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The European Science Notes Information Bulletin (ESNIB) is a compilation of reports on recent developments in European science of specific interest to the US R&D community, and is issued in support of the mission of the Office of Naval Research European Office. It is not intended to be part of the scientific literature. The value of the Bulletin to Americans is to call attention to current activity in European science and technology and to identify the institutions and people responsible for these efforts. ESNIB authors are primarily ONREUR staff members; other reports are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the US Army Research, Development and Standardization Group. US scientists traveling in Europe may also be invited to submit reports.

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ESN INFORMATION BULLETIN

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This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large

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ACOUSTICS

BIOLOGICAL SCIENCES

FLUID MECHANICS

MATERIALS

MATHEMATICS

This meeting held in October 1988 near Ulm, West Germany, covered a variety of topics: representation of curves and surfaces, ray tracing, surface/surface intersections, constructive solid geometry, and containment algorithms. Selected presentations are given under each of those topic headings.

Work reviewed in this report includes: spline approximation, numerical integration, minimal partial realization, algorithms for Intel iPSC/2 hypercube computers, and elliptic pde's. Franke believes that the work on the iPSC/2 will be important to knowledge of how local memory processor computing systems can be used efficiently to solve scientific problems.

Presentations given at this meeting, held in September 1988, are reviewed. The topics are: surface representation, numerical aspects of CAGD, interpolation and approximation patches, solid modeling, and robotics.

MECHANICS

Papers presented at this conference held in September 1988 at Sheffield, UK, are briefly reviewed. Areas touched upon include fluid control, flow measurement, fluid mechanics, flow visualization, biosystems, and new visualization and computer simulation techniques.

The work of the Ernst Mach Institute in Freiburg, West Germany, in armor-antiarmor research and shock and blast research is discussed. The author states that the institute's facilities are a unique material asset. Some of these facilities are integral to the author's discussion of the research he focuses on.

OCEANOGRAPHY

The authors give a brief summary of the findings of the Gibraltar experiment as discussed at this symposium. The experiment returned a large quantity of high-quality data that are suitable for addressing experimental objectives. It has resulted in publication of 13 refereed papers to date, and more are in process.

PAN-EUROPEAN RESEARCH

The technical content of this program – advanced material technologies, design methodology and assurance of products and processes, application of manufacturing technologies, and technologies for manufacturing – is outlined, and comments on implementation of the program in a global K&D context are given.

PHYSICAL ELECTRONICS

PHYSICS

NEWS, NOTES, AND ABSTRACTS

ACOUSTICS

1988 International Conference on Noise Control Engineering

by David Feit. Dr. Feit is the Liaison Scientist for Acoustics and Mechanics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until January 1990 from the David Taylor Research Center, where he is a research scientist in the Ship Acoustics Department.

Avignon, the ancient walled City of the Popes located in the Rhone Valley of France, served as the host city for the 1988 International Conference on Noise Control Engineering. This conference, INTERNOISE-88 – its theme, "The Sources of Noise" – was the 17th in a series sponsored by the International Institute of Noise Control Engineering (I/INCE). It took place from 30 August through 1 September 1988.

The "Groupe Acoustique Industrielle et Environnement" (GAIE) of the French Acoustical Society performed a superb job under the general chairmanship of J. Mattei in organizing this grand and very well attended meeting.

The meeting statistics are truly impressive. There were more than 800 registrants representing industry, government, and university research centers from some 35 countries throughout the world. During the 3-day conference there were three distinguished lectures, 19 introductory session-opening lectures, and close to 400 papers, both invited and contributed, presented during 60 technical oral sessions. Typically, there were at least eight parallel sessions going on in each of the 3 days, both morning and afternoon. In addition there were 11 workshops on controversial and current topics, as well as seven poster sessions. The proceedings, containing 396 papers on a wide variety of topics in noise control engineering, are collected in a three-volume set which was distributed to the attendees. (Additional copies may be available; inquiries should be made to the Noise Control Foundation, P.O. Box 2469 Arlington Branch, Poughkeepsie, NY 12603.)

The talks presented at the meeting can be classified into the following categories:

- Noise sources, both moving and stationary
- Physical phenomena – structural radiation and sound propagation
- Structure-borne sound – generation, transmission, isolation, and reduction
- Effects of noise
- Measurement – sound power and other analysis requirements

After a summary of the opening plenary session and the distinguished lectures, I shall review some of the papers related to structural acoustics and radiation which I found of most interest. Because of the large number of papers presented there are many others no less interesting, but space and time limitations preclude reviewing them here.

Opening Plenary Session

The opening ceremony took place in the Conclave of the Palais des Papes – the magnificent room where, during the 14th century residency of the Papacy in Avignon, cardinals elected the new popes. Although the room is long and narrow and seats more than 600 the acoustics are excellent throughout the room. Opening the meeting, J. Mattei gave a brief history of the room and introduced Dr. Marin, who represented the mayor of Avignon. Marin, a local physician, welcomed the group to Avignon and then discussed some of the environmental concerns of the local authorities. Conservation of the environment is a very current issue to the European citizenry, and as a consequence this conference seemed to attract much public attention in Avignon.

The official opening address of the meeting was presented by W.W. Lang, president of I/INCE, who talked about the challenges faced by noise control engineers in 1988 – using as background the history of noise control legislation and enforcement in the US. He views the US efforts of the 1970's in these areas as a failure, and therefore implores the profession to educate the public better as to the environmental effects of noise so that they can better contest the power structure resisting the moves to change. The noise control profession of today, he feels, is technically ready to meet the engineering challenges in a more realistic and less idealistic way than in the 1970's.

(A complete version of Dr. Lang's talk appears in the INCE publication *Noise News* [Lang, 1988].)

The first of three distinguished lectures was presented by P.G. Jansen (Institut für Arbeits und Sozialmedezin der Universität Düsseldorf, West Germany), who gave a summary of the 5th International Congress on Noise as a Public Health Problem which had just been concluded in Stockholm, Sweden (*Proceedings*, 1988). His summary primarily presented the conclusions of a number of teams who investigated the physiological, psychological, and social effects of noise on man. Again, because of the tremendous environmental movement in Europe, this talk and the meeting it summarized evoked a great deal of interest both within and outside the meeting. The complete text of his speech also appears in the INCE publication journal, *Noise News* (Jansen, 1988).

Active Control

There is much activity in the field of active control in Europe, and one of the principal proponents of this approach to noise control is J.E. Ffowcs-Williams (University of Cambridge, UK), who gave the second distinguished lecture of the conference. Ffowcs-Williams in his many talks on the subject uses the term "anti-sound" to refer to the destructive interference of one signal with another specifically generated to counter the original. In this talk he discussed how the same concept is extended to other fields such as hydro- and acromechanical systems. For example, the stall-flutter and surge phenomenon of turbo machinery is amenable to control using active means – demonstrated at laboratory scale at both Cambridge and MIT. Indeed it was to the latter kind of application that Ffowcs-Williams primarily directed his advocacy in this well-presented and extremely well-received talk.

In addition to this plenary talk there were eight other sessions devoted to active control. These ranged from the theory of active noise and vibration control (ANVC) to its use in enclosed spaces such as ducts and aircraft cabins, vibration control, and the transducers required for its implementation. It is interesting to note that of the 35 papers devoted to the subject only three were presented by US representatives. Judging from the geographic distributions of the presenters both the UK and France seem to be the most active in this area.

Transportation System Noise

The final distinguished lecture, entitled "Speed Related Noise in Land Transport," was given by C.A. Lamure (Institut National de la Recherche des Transports et de leur Securité, Bron, France). This paper reviewed the state of knowledge regarding the relationships between noise output and its annoyance factors to the speeds at which land vehicles operate. He concluded that the theoretical models currently available only provide us with a partial explanation of the phenomenon, and with regard to high-speed rail transport noise, he concludes that aerodynamic noise dominates over wheel-rail contact. European concern with regard to the protection of the environment is further evidenced by the many lengthy discussions within the European Economic Community (EEC) on speed limitations within residential communities. Lamure reviewed the history of such discussions and their relationships to the noise problem.

Structural Acoustics, Structureborne Sound, and Radiation Phenomena

C. Leseur (Laboratoire Vibrations-Acoustique, INSA, Lyon, France) gave the opening lecture on structural vibrations and radiation phenomena. This was in the nature of a review of the state of the art in which he described the two major approaches to analysis of such problems. These he classified as analytical and discretization methods, although it is arguable in my mind not to consider discretization methods as being within the realm of analysis. One therefore should interpret the differences described here as being between those approaches using classical mathematical analysis techniques such as separability solutions, transform solutions, explicitly derived modal solutions, etc., as opposed to those approaches wherein some form of numerical approximation theory is introduced early in the analysis of solving the appropriate mathematical idealization of the physical problem. The analytical approaches Leseur discussed included classical modal analysis, power flow analysis, and statistical energy analysis (SEA) amongst others, while the discretization methods differentiated between the finite element method (FEM) and the boundary element method (BEM). He concluded that current research in this area is very strongly dominated by SEA and power flow techniques.

The talks following Leseur's were for the most part devoted to specific applications of some of the techniques he had outlined. G. Maidanik and J. Dickey (David Taylor Research Center, Carderock, Maryland) presented a paper which attempted to rationalize the SEA methods by going back to the governing equations for a set of simple (one-dimensional) coupled systems, formulating the solution for each member as propagating waves, and then recasting the global response metric in the SEA format. The advantage of this presentation is to retain details in the final results that are presumably forfeited in the classical SEA derivations.

In a later session M.A. Hamdi (Université de Technologie de Compiègne, France) gave an excellent review of both FEM and BEM approaches to vibroacoustic computations. He stated that these techniques are ready to

attack structural acoustic analyses of practical engineering structures, but reminded us that the quality of the results depends critically on the validity of the assumptions being made by the analyst in reducing the physical problem to a numerical algorithm. It is therefore crucial that analysts using these approaches do not treat the powerful programs currently available as "black boxes," but must exercise critical judgment in their application.

There are now in both the European and US markets commercially available programs that are purported to solve structural acoustic radiation and scattering problems. It seems appropriate that these programs should at some point be checked against a benchmark problem and the results of such testing published and discussed in an appropriate forum. One difficulty of course with such a procedure is the relative dearth of benchmark solutions to nonseparable geometric configurations of practical interest, but I would still propose it as a worthwhile effort.

A computational program with the acronym GAP developed at Metravib RDS, an acoustic engineering and consulting firm in Lyon, France, was the basis of a work presented by B. Allgeyer, and T. Robin (Metravib RDS, and Centre d'Etudes et de Recherches Discrétion Acoustique Navale, CERDAN-DCAN, Toulon, France). This program allowed the calculation of the near field of a periodically stiffened submerged cylindrical shell, excited by a force acting on a stiffener flange, which was extended to the far field using a Helmholtz integral formulation. The results of this calculation procedure are to be compared to experimental results in the near future.

There were a number of sessions specifically devoted to structure-borne sound. The introductory lecture in this subject was presented by G. Hubner (Siemens AG, Berlin, West Germany), who reported on the work of the International Standards Organization ISO/TC43/SCI Working Group 22. This group has been studying the methods that can be used to characterize the structure-borne sound emission from machines and equipment. The group is currently preparing a set of documents that will detail special methods to deal with classes of machines. Some schematics of the types of measurements and their locations on idealized views of machines were presented.

The work of another committee, ISO/DIS 9611, was presented by T. Ten Wolde, and J. Verheij (TNO Institute of Applied Physics, Delft, the Netherlands). The measurement quantities used to characterize machines by this group are the velocities of machinery supports, the implementations of which would meet the criteria of simplicity, being inexpensive, and not too time consuming.

In his invited talk, M. Heckl (Institut für Technische Akustik, Berlin, West Germany) discussed why measurands used in air-borne acoustics are not necessarily appropriate for measurements characterizing structure-borne sound sources. Two sessions were devoted to structural intensity, which is the application of vectorial intensity measurements to structure-borne wave propagation. G. Pavic (Electrotechnical Institute, Zagreb, Yugoslavia) gave a survey paper on acoustical power flow measurement in structures, tracing its history from the first attempts by Noiseaux up to the present efforts of his own. In my estimation intensity or power flow measurement whether it be in air-borne or structure-borne applications should not be viewed as a panacea in solving problems, but only as another way of visualizing the sound field which may with some practice lead to a better understanding of the processes involved and thus ultimately contribute to the noise control solution.

Conclusion

This report has only touched on a small number of the presentations. The large number of papers and presenters gives evidence of the continuing and growing interests in the fields of applied acoustics covered in this meeting. The excellent research being pursued in Europe as represented in this meeting should be followed with the greatest interest by US engineers. The state of knowledge represented here leaves no doubt that European noise control engineering is as advanced as that of the US. In fact in some areas; e.g., active noise control, one came away from this meeting with the feeling that perhaps the Europeans may be ahead of us.

INTERNOISE-89, with the theme "Engineering for Environmental Noise Control," will be held in Newport Beach, California, in December 1989. I wish my best to George Maling (IBM, Poughkeepsie), the General Chairman, and Alan Marsh (DyTec Engineering, Huntington Beach, California), Technical Program Chairman. INTERNOISE-88 will be a hard act to follow.

References

Jansen, G., "Noise as a Public Health Hazard," *Noise News*, Vol. 17, No. 6 (1988).

Lang, W.W., "INTERNOISE-88 Opening Address," *Noise News*, Vol. 17, No. 6 (1988).

Proceedings of the International Congress on Noise as a Public Health Problem, Swedish Council for Building Research, Sweden (1988).

2/12/89

Structural Acoustics Research at Plessey Naval Systems, Ltd.

by David Feit

Structural acoustics research of the finest caliber has been going on at Plessey Naval Systems for some time. I first became aware of such work from colleagues who attended the 2nd International Symposium on Shipboard Acoustics held in October 1986 at The Hague, the Netherlands (J. Buiten 1987) where some details were presented. This work in particular takes place at the Plessey Marine facility at Templecombe, which is located at Wilkinthroop House in Somerset, a little over 2 hours by train from London. When I came to ONR London, I contacted J.R. Chapman, the author of one of the works presented at the above meeting, to arrange a meeting at Plessey where I could learn about more recent developments. Since the work in these areas is conducted under contract to the Admiralty Research Establishment at Portland (ARE/Portland), the meeting at Plessey took place with their permission. In fact, S. Tinn and I. Roebuck, both of ARE/Portland, joined me for the meeting at Plessey.

I was first briefed on the overall structure of the company and its contributions to sonar developments for the UK Royal Navy. The work performed by the research group at Templecombe takes place in the Noise and Vibration Group, which comes under the direction of J. Halstead, who gave the introductory brief and served as host for the extremely informative day that I spent there. The work in this group generally falls into four areas. These are: fundamental acoustics; hydrodynamics; self-noise monitoring; and research into the measurement, processing, and analysis of sonar signals.

Experimental Facilities

The work in structural acoustics is primarily directed toward understanding the propagation characteristics of structureborne signals along ship hulls, and the radiation characteristics into the surrounding media of such signals. The approach here emphasizes both experimental and analytical techniques. The principal platform for their experiments is a ribbed cylinder, 6 meters in length and 1.5 meters in diameter, that is reinforced by T-frames periodically spaced along the interior. The information gathered from such a model has been extremely illuminating, so much so, that they have recently constructed a second ribbed cylinder. The latter cylinder was designed with the specific intent of fitting it with a rail system that is used to transport a computer-controlled carriage holding a hydrophone measurement system.

Propagation and Radiation from Cylindrical Shells

A number of different types of tests have been and are planned to be performed on these cylindrical shells. In one type, described by Dr. J. Chapman, the cylinder is impacted at a specific location and the vibration fields generated by such impacts are examined by a multichannel array of accelerometers along the length and around the circumference. The tests have been performed in both a direct mode, and in a reciprocal manner. In the direct mode, a single impact point is selected and the vibration field is sensed at a number of different locations, while in the reciprocal mode, the accelerometer is fixed and the impact locations are varied. The latter approach has the advantage of not requiring matched transducers for multichannel processing, but it does require an automated procedure for varying the impact locations and insuring that the multiple impact forces at each point are repeatable, and recorded. These tests have been performed in air and when the cylinder is submerged. Very good correlations between experiment and theory have been obtained. The theoretical models have been developed at Plessey and also at Topexpress, Ltd., located in Cambridge, UK (I shall be reporting on the work at Topexpress in the future.)

Many of the features characteristic of periodic structures have been observed, including pass and stop bands. The research group has also been examining the effects of damping and water loading, the latter having been shown to produce "pseudo-pass bands" due to the ever-present water borne path that must exist on a fluid-loaded structure. Additionally, acoustic radiation arises because of the supersonic (acoustically fast) components introduced in the pass bands by the periodicity.

Some experiments of the above type have also been conducted in the US, and what I found interesting was the fact that these experimenters have utilized high-resolution spectral techniques in processing their spatial data, whereas we in the US have not as of yet found any advantage to these special techniques in our experiments. It very well might be the different types of excitation techniques that are used in the respective experiments that become the decisive factor.

Acoustic Intensity Measurements

Another type of experiment that was described to me by Dr. P. Watkinson was that in which acoustic intensity measurements are made. In particular, the group has made measurements of the acoustic intensity field in a plane formed by the radially oriented force and a longitudinal generator of the cylinder described above. These measurements have been displayed in a number of different ways. In one format, the intensity vectors are shown as vectors on a grid of points with the length of the vector proportional to the magnitude of the intensity, and in another format in which energy flux lines corresponding to "energy streamlines" are shown (Waterhouse, 1985). Both of these latter visualizations are static in that they visualize the time-averaged intensity (averaged over a cycle) and represent the net energy flow from a radiating structure.

A more recent and extremely interesting development at Plessey that was demonstrated for me is a dynamic display using a computer terminal in which both the reactive and active intensity vectors are shown. The reactive component of intensity which, when averaged over the period of a cycle vanishes together with the active intensity, forms a vector phasor which can be plotted on a screen as a rotating vector with time-varying magnitude. When this is displayed on the screen with varying periods controlled by the operator, one can actually observe the radiating fields and get a much more physical picture of what is happening during the radiation process. Observations of this type will, I believe, inevitably lead to a more intuitive and useful understanding of the noise control attributes of various physical changes made to the radiating objects.

Conclusions

The meeting concluded with I. Roebuck commenting on the utility of this very fundamental research which is leading to practical results that will eventually find their way into applications with the Royal Navy. The work described to me is of the highest caliber and reemphasized in my mind the very significant role that industrial- based research and development can play in advancing our knowledge of structural acoustics.

References

Buiten, J. ed., *Shipboard Acoustics Proceedings ISSA '86* ISBN90-247-34207 (Dordrecht, Boston, Lancaster: 1987).

Waterhouse, R.V., T.W. Yates, D. Feit, and Y.N. Liu, "Energy Streamlines of a Sound Source", *Journal of the Acoustical Society of America* 78 (2), (1985).

11/21/88

BIOLOGICAL SCIENCES

Biotechnology: 15th International Symposium on Controlled Release of Bioactive Materials

by Claire E. Zomzely-Neurath. Dr. Zomzely-Neurath is the Liaison Scientist for Biochemistry, Neurosciences, and Molecular Biology in Europe and the Middle East for the Office of Naval Research European Office. She is on leave until July 1989 from her position as Director of Research, the Queen's Medical Center, Honolulu, Hawaii, and Professor of Biochemistry, University of Hawaii School of Medicine.

Scientists representing over 30 countries gathered in Basel, Switzerland, for the 15th International Symposium on Controlled Release of Bioactive Materials. In addition to the UK and West European countries, Japan, Israel, Canada, and the US were also represented. Attesting to the interest of scientists in this expanding area of biotechnology was a record attendance of over 750 participants – 65 percent from industry, the balance from academic institutions.

The meeting, sponsored by The Controlled Release Society, Inc., took place at the excellent facilities of The European World Trade and Convention Center in Basel. There were 24 sessions with 195 presentations and 67 poster contributions.

The sessions and posters were categorized as follows:

- Oral drug delivery (3 sessions)
- Drug delivery (3 sessions)
- Drug targeting (2 sessions)
- Chemical approach (1 session)
- Insulin delivery (1 session)
- Parentals (2 sessions)

- Agricultural/veterinary (3 sessions)
- Fundamentals (4 sessions)
- Peptide/protein delivery (1 session)
- Transdermal delivery (4 sessions)

Proceedings of the symposium are available from the Controlled Release Society, Inc., 15 Nottingham Drive, Lincolnshire, Illinois 60015.

With the more than 250 scientific contributions at the 15th International Symposium on Controlled Release, it is only possible to present information in this short report on a few selected contributions. Overall, the quality of the presentations was very high. This report deals primarily with contributions from European scientists since that is the primary function of *ESNIB*.

In his plenary lecture, G. Poste (Smith Kline & French Laboratories, Philadelphia) offered an insightful and thorough evaluation of new methods for drug targeting. The second plenary lecture by R. Wilkins (Department of Agricultural and Environmental Science, University of Newcastle upon Tyne, UK) showed that sophisticated targeting methods are presently the goal of many researchers working on crop protection.

The Presidential lecture by R. Langer (MIT, Cambridge, Massachusetts) was a futuristic presentation addressing some of the unusual and challenging applications in the near future of controlled release drugs, such as use for brain tumor treatment. He showed that controlled drug elimination and controlled organ reconstruction are new fields with much relation to controlled release.

Drug Delivery

Interesting new applications of polymers or modifications of existing devices were presented in the drug delivery session. D. Dreher (Central Research and Development Pharmaceutical Rohm GmbH, Darmstadt, West Germany) presented recent studies on the use of poly(meth)acrylate-coated particles and compression into controlled release. Dreher and his group optimized coating of spherical and irregular particles in fluid bed systems to obtain sustained-release preparations of high mechanical stability for compression into quickly disintegrating tablets that maintain their controlled release profile. With sufficient fillers and disintegrants in the tablet formula, the disintegration time was kept below 5 minutes so that nearly unaffected coated particles were released immediately. Stable taste masking was achieved on Parcetamol crystals with coating of hydrophilic poly(meth)acrylic ester (EUDRAGIT RL 30 D); sustained release tablets were made from Theophylline granules and potassium chloride crystals coated with ethyl-acrylate-methyl-methacrylate copolymer (EUDRAGIT NE 30 D) as well as with hydrophilic poly(meth)acrylic esters (EUDRAGIT RL/RS 30 D).

Recent developments in the saga of utilization of polyethylene oxide) hydrogels as controlled release devices were presented by M. McNeil (Department of Pure and Applied Chemistry, University of Strathclyde, Glasgow, UK).

P. Columbo (Institute of Pharmaceutical Technology, University of Parma, Italy) and his collaborators continue to impress with the development of "simple" compressed tablet systems for zero-order release. The latest development worth mentioning is swellable matrices restricted by impermeable coatings. Some of these systems show zero-order release because of a delicate balance between coated edges, controlled swelling, and restricted diffusion.

An interesting report on drug loading conditions for highly dosed cross-linked poly(vinylalcohol)(PVA) matrices with controlled release properties was presented by V. Beltrami (School of Pharmacy, University of Geneva, Switzerland) and coworkers. These investigators found that swelling, loading, and release tests showed the strong influence of the degree of cross-linking in the matrices. The amount of drug contained in the matrices could be modulated by the cross-linking density of the polymer and by the concentration of the loading situation. These researchers showed that swelling systems can incorporate and release therapeutic amounts of a drug with a controlled rate over many hours. Beltrami said that modification of the polymer could be an additional step in improving these devices, which have a significant potential.

F. Lescure (School of Pharmacy, University of Geneva, Switzerland) and coworkers dealt with the evaluation of a new class of synthetic polypeptides, the poly(tert-butyl-oxycarboayl-methyl) glutamates [POMEG], with various degrees of esterification, as an injectable or implantable drug delivery system. These investigators found that implanted POMEG polymers show a normal tissue reaction either with or without progesterone and no evidence of muscle damage was seen within 14 days. *In vivo* release rates obtained with the implants showed their potential as drug delivery systems either for short- or long-term therapy.

Drug Targeting

These sessions provided a series of excellent presentations: R. Duncan (UK) on the biocompatability of certain synthetic polymers designed for targeting, R.M. Gilley (US) on microencapsulated antigens, and J. Senamoto (Japan) on liquid microspheres for targeting.

Duncan and her coworkers (Cancer Research Campaign Laboratory, Department of Biological Sciences, University of Keele, UK) have over the past few years

been developing soluble synthetic polymers such as poly (amino acids) and dextrans for use in targeted drug delivery (particularly cancer chemotherapy). In addition they have also been developing a portfolio of *in vitro* and *in vivo* tests useful for general definition of the biocompatability of soluble polymers. These investigators have also recently found that conjugation of proteins (transferrin and human immunoglobulin IgG) to HPMA copolymers reduces their immunogenicity. [HPMA is N-(2-hydroxypropyl)methacrylamide.]

Microsphere formulations containing antigens that will effectively immunize man and other mammals against a wide variety of antigens after oral administration have been developed by R. M. Gilley and colleagues (Controlled Release Division, Southern Research Institute, Birmingham, Alabama). Moreover, by combining microspheres that are 1 to 5 microns in diameter with microspheres of 5 to 10 microns, a formulation is obtained which results in the induction of both systemic and mucosal immunity.

J. Sunamoto and coworkers (Laboratory of Artificial Cell Technology, Department of Industrial Chemistry, Faculty of Engineering, Nagasaki, Japan) have carried out extensive studies on stable and cell-specific lipid microspheres (LM) for delivery of lipophilic drugs. The LM are oil droplets of glycerides with surfaces covered by a lecithin monolayer. LM is an aqueous emulsion and a rather stable colloidal system compared with liposomes. These investigators carried out physicochemical characterization of LM as well as studies aimed at making LM more stable and cell-specific. They found that LM can be made more stable and cell-specific by coating with appropriate polysaccharide derivatives in a manner similar to liposomes.

Further evidence of nanoparticle utilization for controlled release application was provided by J. Kreuter (Institute for Pharmaceutical Chemistry, Johann Wolfgang Goethe University, Frankfurt, West Germany), who described preparation methods and physicochemical characterization of nanoparticles. He said that it is necessary to deliver the drug to the designated site of action in the most efficient way possible. Targeting the drug to the site of action either by using a prodrug or a sophisticated drug delivery system would not only improve the therapeutic efficiency but also enable a reduction in total dose of the drug which must be administered to achieve a therapeutic response, thus minimizing unwanted side effects.

One possible means of reaching the above outlined goal may be a delivery via colloidal drug delivery systems. Chiefly due to their small particle size, these systems offer advantages for many medical, agricultural, veterinary and industrial applications. In medicine, colloidal preparations themselves lend to parental administration and may be useful as sustained-release injections or for the delivery of a drug to a specific organ or target site, according to Kreuter. Colloidal carrier systems which have been developed include liposomes and nanoparticles. Nanoparticles are colloidal particles ranging in size from 10 mm to 1000 nm and consist of a polymeric material into which drugs, enzymes, or antigens are dissolved, encapsulated, and/or adsorbed. These nanoparticles can be manufactured in an aqueous surrounding medium using emulsion polymerization, solvent evaporation, interfacial polymerization of an oil\water emulsion, or the desolvation of macromolecules. Nanoparticles in an oily surrounding phase can be either produced by a reverse type of emulsion polymerization or by the denaturation of macromolecules dissolved in a highly dispersed water\oil emulsion.

According to Kreuter, the most important characterization method for these systems is transmission electron microscopy. Other methods include particle sizing by photon correlation, and the determination of the molecular weight, drug sorption characteristics, electrophoretic mobility, density, surface area, and contact angles.

Transdermal Delivery

The transdermal sessions attracted a very large audience, as they have in past meetings sponsored by the Controlled Release Society, Inc. There were a large number of presentations dealing with transdermal delivery but it is only possible to report on a few selected papers in this relatively short report.

K.R. Shah and coworkers (Hercon Laboratories, South Plainfield, New Jersey) presented an interesting report on a novel transdermal drug delivery system which is ultrathin (< 0.1 mm, breathable oxygen and moisture-vapor permeable) and has excellent conformability to skin. The purpose was to minimize one of the problems associated with transdermal drug delivery – the occurrence of adverse skin reactions at the application site, some of which are facilitated by the occlusive nature of the patch. Shah said that the system, composed of a three-layered polymeric structure, is ideally suited for topical application of medications such as antiinfective, antiinflammatory, and antifungal conditions. This system is also suitable, Shah said, for the transdermal delivery of relatively potent, nontoxic, and nonvolatile drugs. Shah and his group investigated such a patch providing controlled release of chlorhexidine diacetate (CHA) for use as an antiseptic dressing for wound and other applications. Chlorhexidine is a potent antiseptic agent which exhibits a broad spectrum activity, low toxicity, and has a very high therapeutic index.

A report on another new technique for transdermal delivery was presented by R. Lichtenberger (Department of Pharmaceutical Technology, University of Bonn, West Germany). He described a novel technique for manufac-

turing adhesive polymer patches for transdermal drug delivery by using aqueous polymer dispersions. According to Lichtenberger, such dispersions can be obtained under variable polymerization conditions to yield a broad range of individually tailored polymer types, comonomer ratios, particle sizes, and degrees of cross-linking. Thus, ready access to specially designed polymer formulations is available to meet the requirements of each individual drug. Lichtenberger said that the use of such systems is exemplified by a number of strategies of how to optimize the thermodynamic activity of the drug in polymeric matrix systems – for example, by selecting favorable drug/polymer combinations, and by the use of additives or cross-linked polymer dispersions.

D.R. Friend (Controlled Release and Biomedical Polymers program, SRI International, Menlo Park, California) spoke about transdermal permeation enhancers for drugs. He said that low skin permeabilities require impractically large devices if useful drug delivery rates are to be achieved. One way to deliver more drug via the transdermal route is to include in the formulation, a chemical or chemicals which reversibly reduce the barrier properties of the skin. Friend and coworkers, in their work with the contraceptive steroid, levonorgestrel, investigated a number of chemicals for their ability to act as permeation enhancers. These investigators found that ethyl acetate is a very potent permeation enhancer for not only levonorgestrel but also for a variety of other drugs. Friend described the work with ethyl acetate and other related esters as permeation enhancers for drugs.

A controlled-release drug system for achieving transdermal controlled systemic administration of compounds such as progestin, levonorgestrel, and estrogen for fertility regulation in females has been developed by Y. Chien and coworkers (Controlled Drug Delivery Research Center, Rutgers University, College of Pharmacy, New Jersey). This controlled-release patch (transdermal contraceptive device) permits the administration of the drug continuously over a period of 1 week with the woman wearing only one patch each week for 3 consecutive weeks during each cycle. This transdermal approach eliminates the side-effects often encountered with oral delivery of contraceptive drugs.

B. Mollgaard (Royal Danish School of Pharmacy, Copenhagen, Denmark) described a careful study she and her group conducted on the ability of N-methyl pyrrolodine (NMP), polar lipds, oleic acid (OA), linoleic acid (LA), oleyl alcohol (OA1), and azone to increase the percutaneous delivery of drugs such as metronidazole, lidocaine, and acyclovir across full-thickness human skin *in vitro*. The aim of this work was to examine fundamental mechanisms of various penetration enhancers using different types of model drugs. Acyclovir, an antiviral drug active against herpes virus is a highly polar drug; lidocaine (a local anesthetic) is a more lipophilic drug, and metronidazole (a chemotherapeutic) supposed to be effective in the topical treatment of rosacea, has intermediate hydrophilic/lipophilic properties.

The results presented by Mollgaard showed that the effect of a penetration enhancer is highly dependent on the polarity of the drug and the cosolvent in the vehicle. Addition of a small amount of OA1 to a propylene glycol (PG) vehicle provides for a large increase in the skin permeation of metronidazole and acyclovir, whereas permeation of lidocaine is not affected by fatty acids. Mollgaard and her group also found that permeation of metronidazole and lidocaine was unaffected by the inclusion of NMP in the PG vehicle, whereas NMP in mixture with isopropyl myristate (IMP) delivered two to four times as much drug as the PG-vehicle during 24 hours. Mollgaard said that the effect of NMP is related to its concurrent permeation in the skin. Replacement of PG with IMP in the vehicle produced an extremely fast permeation of NMP, presumably as a result of the substance being easily released from the skin.

H.E. Bodde (Center for Bio-Pharmaceutical Sciences, Leiden, the Netherlands) presented studies on a potentially important area of transdermal delivery – i.e., transdermal peptide delivery. Bodde said that there is an increasing interest in the use of peptides as drugs in the treatment of various diseases since peptides have a number of important advantages over nonpeptidergic drugs: (1) they are often very potent and may already be effective when present at the target site at very low concentrations and (2) another favorable characteristic of peptides is their endogenous origin, which minimizes the risk of unwanted side effects. However, the delivery of peptide drugs into the human body is handicapped by their instability towards proteolytic enzymes, thereby making oral delivery very inefficient. The injection route of administration, although effective, often requires trained personnel and can be painful and irreversible. Therefore, Bodde and coworkers focused on transdermal delivery of peptide drugs. The transdermal route is a good alternative method of administration for peptides since it avoids hepatic first-pass metabolism and enzymatic breakdown in the gastro-intestinal tract. Also, according to Bodde, the delivery via skin is especially attractive for peptides for which systemic levels have to be maintained within the therapeutic range over a prolonged period of time, such as for vasoactive peptides, LH-RH analogues, etc. Also, transdermal dosage forms are often easy to apply and to remove, and, given the proper choice of ground material, tend to evoke minimal – if any – dermatological side-effects.

Bodde described two aspects of transdermal peptide delivery: transpeptidermal penetration and intra- (epi-) dermal biotransformation, using the example of Des-enkephalin-y-endorphin (DEyE), a highly potent neuropeptide which has been implicated in schizophrenic

psychoses. Bodde and colleagues found that the dodecapeptide (DEyE) is capable of passing the human stratum corneum at a flux rate of about 10 pmol/cm^2/h *in vitro* in the absence of flux enhancers. Bodde said that for therapeutic effects, transdermal fluxes will most likely have to be enhanced and that glycerol may be a possible candidate for a flux enhancer. According to Bodde, the half-life of the peptide in contact with either cultured human skin cells or fresh human skin, is surprisingly long and will probably not be a major obstacle for transdermal peptide delivery.

Z. Liron and coworkers (Department of Physiology and Pharmacology, Tel Aviv University, Israel) reported studies on the role of an enhancement factor in the penetration of adenosine into excised human skin from binary vehicles. These investigators found that a purine riboside such as adenosine is capable of diffusing across human skin when delivered from a binary vehicle containing an alkanoic acid such as propionic or hexanoic acid. The permeability coefficient from such mixtures, hence flux, could be modulated by a change in the composition of the donor vehicle. Thus, zero-order delivery at a given desired rate could be achieved by proper design of the donor vehicle.

Fundamentals Sessions

K.V. Rango Rao (School of Pharmacy, University of Geneva, Switzerland) presented an informative talk on factors affecting the bioadhesion of coated microparticles. He and his group have developed some very useful bioadhesive microparticle systems. In their bioadhesion studies, Rao and coworkers used hydrophilic polymers such as hydroxypropylmethylcellulose (HPMC) and methylcellulose. Polycarbophil (PC), sodium carboxymethylcellulose (Na CMC), and pectin (PT) were also used to coat the microparticles. To avoid the influence of the core on the bioadhesive property of the polymer coat (particularly while evaluating the mucoadhesion of the polymers and while studying the various factors affecting the bioadhesion) glass beads (0.45- to 0.5-mm diameter) were chosen as model particles. Rango Rao and his group found that increase in the viscosity and thickness of the HPMC coat increased the adhesion. A mixture of anionic and nonionic polymers had no effect. Particles adhered better to the jejunum compared to the proximal or distal end of the intestine. Contact time and moisture content were found to be important for celluloses, but not for polycarbophil, and that the viscosity of the mucus influenced adhesion.

There were four excellent reports in the fundamental sessions by R. Langer and his group (Department of Applied Biological Sciences, MIT, Massachusetts). The topics covered were (1) mechanistic studies of polyanhydride degradation, (2) an ultrasonic method for testing fluid permeation in matrix devices, (3) study of the stability of biodegradable polymers in solid state and in organic solution, and (4) copolymer composition and microstructure of polyanhydrides. Various members of Langer's group presented these reports.

A detailed and interesting study of elastic solutions of polymer in water was presented by W.E. Roorda (Leiden University, the Netherlands). He and his coworkers investigated hydrogels of p-hydroxypropylmethacrylate (pHEMA) and p-dihydroxypropylmethacrylate (pDHPMA) with thermal analysis and nuclear magnetic relaxation (NMRx). They obtained the following results: differential thermal analysis showed that the abnormal thermal behavior of water in pHEMA gels is caused by the development of metastable nonequilibrium situations, due to a glass transition in the freezing gels. The total amount of freezable water in the gels is independent of the cross-linker content. Adiabatic calorimetry, which is a technique that allows much better approximation of equilibrium situations (according to Roorda), showed only one single melting peak. Isoperibolic calorimetry showed that only 1 mole of water per monomer pHEMA has an enthalpic interaction, which is less than the amount of nonfreezing water. NMRx experiments showed that on a millisecond scale no different types of water are detectable in the water in the gels. The rotational mobility of the water was determined by the polymer content, and not by the cross-linker. Roorda said that this conclusion was valid for pHEMA gels in water and a number of aqueous solutions, as well as for pHEMA solutions in water/$NaClO_4$, as for pDHPMA gels. Therefore, Roorda concluded that no evidence was found for the presence of different classes of water in hydrogels, but that they could be considered as solutions of polymer in water that possess a certain shape and elasticity. As such according to Roorda, they might well be regarded as "Elastic Solutions" and that these results may be useful for the development of drug delivery systems.

Insulin Delivery

The session on insulin delivery attracted a lot of interest. Of particular interest were two presentations by researchers from Israel and the US which dealt with novel methods of insulin release.

J. Kost (Department of Chemical Engineering, Ben-Gurion University, Beersheva, Israel) described a novel method of insulin release with emphasis on autoregulated systems which are based on ultrasound triggering. Kost said that although the area of polymeric-controlled drug delivery systems has been a field of increasing interest, relatively little attention has been given to developing systems in which the rate of delivery can be manipulated externally. There are a number of situations where augmented delivery on demand could be beneficial, ac-

cording to Kost. These include delivery of insulin for patients with diabetes mellitus, antiarythmics for patients with heart rhythm disorders, and nitrates for patients with angina pectoris, as well as selective beta-blockade, birth control and general hormone replacement, immunization, cancer chemotherapy, and long-term immunosuppression.

The objective of the research of Kost and his colleagues was to develop controlled-release systems which would resemble the normal homeostatic process in which the amount of drug released could be affected according to physiological needs. These investigators found that release rates of biologically active substances from a polymeric matrix could be modulated repeatedly from a position external to the environment of use by an oscillating magnetic field or ultrasonic energy. In their studies, Kost and coworkers investigated insulin delivery by external modulation.

R. Siegel (School of Pharmacy, University of California, San Francisco) reported on an implantable, self-regulating, mechanochemical insulin pump. Siegel and his colleagues are working on a pump which has been designed to exploit the property of swelling/deswelling highly swollen gels in response to step pH changes between pH 5 and 6. A highly swollen gel can alter its volume quickly in response to a change in pH. They use the pH-sensitive hydrogel as a force generator that is turned on when the pH is lowered (in response to raised blood glucose via a glucose oxidase/catalase membrane). Expansion of the hydrogel displaces the insulin out of the device. A system of valves guarantees that when the hydrogel swells in response to lowered blood glucose, water will flow into the device at a site that does not communicate with the insulin formational. This "mechanochemical pump" has the potential of modulating insulin release quickly in responses to changes in blood glucose level. Since it directly converts chemical energy to mechanical energy (pumping), no moving parts are necessary. Siegel thinks that a 1-year's supply of insulin could be stored in semisolid form in a pump whose volume is approximately 10 cc.

Chemical Approach Session

As Special Invited Lecturer, H. Bundgaard (Department of Pharmaceutical Chemistry AD, Royal Danish School of Pharmacy, Copenhagen, Denmark) presented an excellent report on prodrugs for controlled drug delivery. He said that a promising approach to improve drug delivery is chemical transformation of the active drug substances into *per se* inactive derivatives (prodrugs) which convert to the parent compounds by virtue of enzymatic or chemical lability, or after reaching the site (or sites) of action. Bundgaard presented recent examples from his laboratory with respect to the utility of this approach in improving the delivery of various drugs including peptides. Esters of pilocarpic acid have been developed as prodrugs of pilocarpine with improved bioavailability and extended duration of action. Bundgaard discussed the physicochemical and biopharmaceutical properties of these prodrugs.

Bundgaard also dealt with the properties of various timolol prodrugs possessing enhanced corneal absorption characteristics. Various prodrugs of allopurinol and 5-fluoruracil were prepared by Bundgaard and coworkers with the aim of improving the rectal and parental delivery characteristics of the drugs. Bundgaard said that N-acyl and N-acyloxymethyl derivatives appear to be promising prodrugs. Bundgaard also presented some studies showing the utility of the prodrug concept to improve the delivery of small peptides. Various bioreversible derivatives of pyroglutamyl peptides were developed by Bundgaard and his group and shown to protect the peptides against degradation by pyroglutamyl aminopeptidase.

C.J.T. Hoes (Department of Chemical Technology, University of Twente, Enschede, the Netherlands) presented an interesting report on soluble biodegradable carriers for targeted drugs. Hoes said that the use of an intermediate polymeric carrier in antibody-drug conjugates could increase the amount of drug transported by the protein and enhance the therapeutic effectivity of the conjugate. Hoes and his coworkers have proposed poly (α-L-glutamic acid) as a carrier for adriamycin (ADR). Poly (α-L-glutamic acid, (PGA) is a nontoxic and biodegradable polymer. Hoes said that for the purpose of coupling of PGA-ADR conjugates with antibodies, a thiol group has to be present at the polymer chain end. However, PGA prepared by standard routes contains an unreactive pyroglutamyl end group. By incubation of PGA with pyroglutamate aminopeptidase and conversion of the amino end group to a thiol end group, Hoes and coworkers were able to increase the yield of thiol-PGA from 11 percent without enzymatic deblocking to 33 percent. Hoes said that the potential of antibody conjugates of ADR using thiol-PGA and peptide spacers between drug and carrier to effect endocellular drug release are being studied by him and his group in animal experiments.

Formulation of silicone laminates for long-term zero-order release of peptides by an osmotic pressure-driven mechanism was described by M. Hoth (School of Pharmacy, Bonn, West Germany). Essentially, this study dealt with the formulation of a biocompatible delivery system for long-term zero-order release of hydrophilic drugs – for example, peptides. The laminate device consists of a poly(dimethylsiloxane) [PDMS] reservoir matrix which contains the drug and hydrophilic excipients, and a PDMS membrane with suitable pores. Drug release is controlled by the following sequence: (1) osmotic pressure-driven uptake of water vapor through the continuous

phase of the polymer, (2) establishment of hydrostatic pressure by aqueous dissolution of drug and excipients, and (3) pressure-driven transport of drug solution through the preformed porous network of the membrane. Hoth said that the release characteristics depend critically upon the physical and physicochemical properties of the excipients used for formulation of the laminate. According to him, the delivery systems he and his group developed are capable of achieving zero-order drug release for several months with about 70 percent of the total drug load released during this period. He also said that it is noteworthy that no initial drug dumping occurs during the release process.

Parenterals Sessions

O. Vaizoglu (School of Pharmacy, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland) presented an interesting report on the use of pharmacosomes as drug delivery systems. Vaizoglu said that pharmacosomes can be defined as a colloidal dispersion of drugs covalently bound to lipids. Pharmacosomes may exist as ultrafine vesicular, micellar, or hexagonal aggregates depending on the chemical structure of the drug-lipid complex. Viazoglu reported that the advantage of such a drug delivery system is that the Pharmacosome is the active principle (pharmacon) and the carrier (soma) at the same time. He and his group esterified Pindolol, a beta-receptor blocking agent, with glycerol monostearate via a spacer and isolated it as the maleate salt. The resulting compound was highly amphiphilic, thereby showing self-dispersion properties. Vaizoglu and coworkers studied the pharmacokinetical behavior of this ultrafine aqueous dispersion (pharmacosome) of the pindolol ester following intravenous and peroral administration to beagle dogs. An anticancer drug, Chlorambucil, was investigated by the same approach in Sprague-Dawley rats. The results indicated full retention of anticancer activity of the parent drug in the glyceride ester form.

A detailed study of the influence on the therapeutic activity of the adsorption percentage of Bexatolol Chlorhydrate onto nanoparticles used as an ophthalmic drug delivery system was presented by Ph. Maincent (Laboratory of Galenic Pharmacy, Nancy, France). He said that the objectives of the study were to evaluate the effects on the reduction of the intraocular pressure (IOP) in glaucomatous rabbits, of different parameters such as: (1) the adsorption percentage of an antiglaucomatous drug (Betaxolol chlorhydrate) onto isobutylcyanoacrylate nanoparticles, (2) the binding type of the drug onto the surface of nanoparticles (hydrophobic or electrostatic), and (3) the charge at the nanoparticles' surface. By modification of the surface charge, Maicent and his group found that it was possible to adsorb either 30 percent (surface charge = -15 mV) or 70 percent (surface charge = -30 mV) of the same drug concentration. When administered in glaucomatous rabbits in comparison with commercial eye drops, the suspension with the highest adsorption level lowered considerably the overall therapeutic activity. The suspension with the lowest drug payload increased the maximal therapeutic response and significantly prolonged the reduction of IOP in time. Maincent said that he and his group had clearly showed that, regarding the ocular administration, surface charge of the particles and binding type of the drug to the nanoparticles were much more important parameters than the adsorption percentage onto the nanoparticles because the first parameter influences the residence time of the particles in the cul de sac and the second considerably alters the release rate of the drug from the particles' surface.

An interesting collaborative study by a US group and a Swedish group was presented by D. Mason (Controlled Release Division, Southern Research Institute, Birmingham, Alabama). The Swedish collaborator was A. McRae-Degueurce (Unit-259, University of Göteborg, Sweden). The study was concerned with biodegradable poly (DL-lactide-co-glycolide) microcapsules for controlled release of catecholamines to the central nervous system (CNS). Mason said that injectable, controlled-release microcapsules serve two functions: (1) they protect substances from degradation and (2) they release substances at a controlled rate in a target site – up to months. These investigators applied this technology to the CNS as a means of delivering agents which do not cross the blood-brain barrier or are rapidly degraded. Specifically, L-DOPA or dopamine were encapsulated in poly (DL-lactide-co-glycolide). Rats received bilateral injections of 6-hydroxy dopamine in the medial forebrain bundle. Following recuperation from lesions, the animals received a unilateral injection of the capsules in the striatum. Rodents were perfused with 4 percent paraformaldehyde either 24 or 48 hours after receiving the capsules. The brains were processed for immunocytochemistry with a tyrosine hydroxylase antibody. The results demonstrated intense fluorescence in the region where the capsules had been implanted. The contralateral striatum was devoid of fluorescence. Mason said that because the injectable capsules appear to be ideal for delivering drugs or other substances to specific brain regions, this technology has considerable potential for both clinical and basic research.

Conclusion

The International Symposium on Controlled Release of Bioactive Materials dealt with topics of considerable interest to scientists in basic research as well as those in R&D divisions of industrial concerns. This was evidenced not only by the large number of participants at the con-

ference but also by the presence of many representatives from industrial concerns. Controlled release of bioactive materials is of great importance not only for the medical area but also for agriculture and veterinary medicine. The contributions presented in this report represent selected presentations based on the quality of the research as well as, in many cases, descriptions of innovative ideas and techniques. Although there were several excellent contributions from US researchers, only a few are mentioned in this report since the emphasis on research by European scientists is the primary objective of the *ESNIB* reports. It is evident from the work of the European scientists presented in this report that they are carrying out research of high quality and imagination.

2/12/89

FLUID MECHANICS

Research on the Fluid Mechanics of Turbomachinery and Engines: Research at the University of Cambridge and Imperial College

by David Feit. Dr. Feit is the Liaison Scientist for Acoustics and Mechanics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until January 1990 from the David Taylor Research Center, where he is a research scientist in the Ship Acoustics Department

On a recent visit to the UK, Timothy Doyle and Jack Ward, of the David Taylor Research Center (DTRC) Propulsion and Auxiliary Machinery Department toured various academic and industrial facilities doing work related to propulsion and auxiliary machinery research being done at DTRC. I accompanied them on their visits to two academic institutions. These were the Whittle Laboratory at the University of Cambridge and the Mechanical Engineering Department of the Imperial College of Science and Technology.

This brief report documents what we saw and heard during these two visits. This field of research is not within my area of expertise so I shall not attempt to evaluate, but merely bring to the reader's attention some idea of the scope of activities being pursued at these two particular institutions in the areas of turbomachinery flow and internal combustion research. The program at the Whittle Laboratory was primarily devoted to the former while the group we talked with at Imperial College dealt more with the latter.

The Whittle Laboratory, University of Cambridge

The Whittle Laboratory, part of the University of Cambridge Engineering Department, specializes in research on the aerodynamics of internal flows of turbomachinery. The laboratory is part of Division A of the Engineering Department, which comes under the purview of Professor Sean Ffowcs-Williams. Work in this division generally falls into the categories of acoustics, turbomachinery, internal combustion engines, and fluid mechanics. Our host at the laboratory was Dr. Thomas Hynes, who, starting as a graduate student, has been affiliated with the laboratory for more than 10 years.

The Director of the Whittle laboratory is Dr. J.D. Denton; the staff currently includes Drs. N.A. Cumpsty, W.N. Dawes, H.P. Hodson, T.P. Hynes, and J.B. Young, all of whom are also University Teaching Officers. Although both are now retired, Sir William Hawthorne and Dr. D.S. Whitehead continue to be involved with various projects at the laboratory. The other staff members include seven postdoctoral fellows, six research assistants, and about 15 research students pursuing advanced degrees. The university supports the physical plant of the laboratory and the salaries of the teaching fellows. The rest of the income comes from external sources; this figure being in the order of £500,000 (about $920,000). Of this, approximately one-half comes from Rolls Royce and the remainder from the Science and Engineering Research Council (SERC), the Central Electricity Generating Board (CEGB), the GEC Corp, and Parsons and Halsett.

The work is approximately half experimental and half theoretical. Much of the theoretical work is in the area of internal flow modeling. This work is pursued primarily under the leadership of Denton and Dawes. In fact, these two individuals have developed software packages that are being sold on a commercial basis and reported to be

used quite extensively in the US. Although much of Denton's and Dawes' work up to this time has been in the numerical modeling of compressible flows they are becoming more involved in the modeling of incompressible flow, especially as related to the flow around open and ducted propellors.

The laboratory's experimental facilities include a closed circuit transonic wind tunnel, two large low-speed rotating machines, a number of low-speed wind tunnels, several low-speed turbines and compressors, and a blowdown combustion rig. These facilities are being used to support research in a number of areas such as: determination of the conditions leading to axial compressor stall, development of an understanding of the losses associated with tip leakage flows in axial turbines; study of the effects of compressor endwall boundary layer flows on stall, which requires detailed measurements of the flow in the tip-clearance region; and the study of combustion instabilities that can occur in the afterburner of a gas turbine engine and the active control of this phenomenon – referred to as afterburner reheat buzz. In the latter project the investigators, led by Dr. Ann Dowling, have reported a 20-dB reduction in the pressure spectrum level at the buzz frequency by actively controlling the mass flow of the air-fuel mixture. The projects mentioned are just a small sample of the many activities currently being pursued at the laboratory.

Imperial College of Science and Technology

The focus of our visit to Imperial College was the Mechanical Engineering Department, located on Prince Consort Road in London. (See *ESN* 41-9:508-510 [1987] for a report of a previous visit.) Our initial contact was with Professor J. H. Whitelaw, who supervises the work in these areas. He was not able to be with us during our visit, but he arranged for us to be hosted by two of his associates, Drs. Costis Vafidas and Siva Sivasegaram. The work pursued here covers a wide spectrum from elementary fluid mechanics to combustion investigations in internal combustion engines to experimental high-speed projectile (gun) studies designed to obtain data required to validate numerical modeling codes.

The latter study is being funded by the US Army and, coincidentally, is being conducted by a US citizen. It is also of interest to note that the half dozen or so projects that we were shown were all being conducted by non-UK nationals.

A number of the studies were related to the mixing phenomenon prior to ignition in internal combustion engines. We observed a rig that was being used to examine the spray characteristics, droplet size and velocity, and the effects of swirl in a diesel combustion engine. In a gasoline combustion engine experiment, the effects of swirl, spark location, and flame propagation were being examined.

Much of the work seemed to be concerned with the visualization of the flow processes in the cylinders of reciprocating engines with a view to obtaining data used to validate numerical modeling work. Special reciprocating combustion devices were equipped with quartz pistons and windows which permit laser penetration and measurement of the combustion process. For a project sponsored by NASA Lewis the investigators are using liquids in transparent plastic fixtures where the liquid is made to have the same refractive index as the plastic so that the laser light can be used to visualize the flow patterns without distortion. From what I was told, this is a rather unique experimental arrangement. In addition, the laboratory is equipped with very extensive laser Doppler velocimetry instrumentation.

The work being conducted under Whitelaw's supervision is very extensive, employing more than 40 individuals. The support comes from a variety of sources, both European and American. These include the UK's Ministry of Defense, ICI, SERC, the Central Electricity Generating Board, and the Coal Board, and the US Department of Energy, and NASA.

Conclusions

The work being performed in the areas of turbomachinery and internal combustion engines at both the University of Cambridge and the Imperial College of Science and Technology combines both theoretical and experimental approaches in a complementary way. Each of the two centers appear to be well funded by external sources. It appears also that the work at these two centers is known to US researchers in the field. In the case of the Imperial College work, there are a number of projects being sponsored by US agencies. I was interested to note that at both laboratories a considerable amount of effort is being expended in generating experimental data that will be useful in validating computational codes that in the future could make much of the experimental efforts and expense less necessary, and may reduce the time needed to evaluate new design concepts in gasoline and diesel engines.

11/17/88

MATERIALS

Vacuum Arc Coating and Surface Alloy Research at Tel Aviv University, Israel

by Marco S. Di Capua. Dr. Di Capua is the Liaison Scientist for physics in Europe and the Middle East for the Office of Naval Research European Office. He is an experimental physicist on leave until August 1990 from the Lawrence Livermore National Laboratory of the University of California.

Tel Aviv University's Professor Raymond L. Boxman and Samuel Goldsmith investigate a vacuum arc process to coat substrates. These coatings can be used for:

- Corrosion protection with materials such as aluminum and stainless steel which cannot be deposited with standard electrochemical techniques
- Deposition of surface-hardening coatings such as diamond and TiN for wear protection on tools and scratch-protection on optical components
- Deposition of ZrO for thermal insulation
- Deposition of W and Al on wafers
- High dielectric-constant coatings on metal substrates
- EMI/RFI shielding coatings on molded plastic components
- Reflective coatings for architectural and other glasses.

The vacuum arc coating process is well known to anybody who has operated electrical arc discharges in vacuum. In these discharges, the cathode material constitutes the interelectrode plasma column. Consequently, a "cathode vapor arc" would be a better name for this type of discharge. The plasma condenses on any cool surface that intercepts it, and usually deposits on the anode and the walls of the vacuum vessel. Unless the arc is used specifically to produce a coating, these deposits are a nuisance since they darken observation windows and degrade high-voltage feedthroughs.

Vacuum arc coating technology has been known for more than a century. T. A. Edison applied for a patent for production of phonogram records, using this process, in 1888. In a recent review paper (Boxman et al., 1988) Boxman traces the developments of vacuum arc technology from this first patent to the present. He points to the advances contributed by Japanese researchers in the late 1960's to early 1970's, followed by Soviet contributions in the late 1970's to early 1980's, and the development of industrial techniques for nitride coatings in the mid 1980's.

In low-current vacuum arcs, plasma and emission of electrons originate from one or more intensely luminous cathode spots that emit a nearly fully ionized plasma jet in which ions with energies in the range of 25 to 75 eV carry about 10 percent of the spot current, which is typically 10 to 150 A (Boxman, 1986). These spots are very mobile and sometimes eject droplets of material, called macroparticles that are sometimes evaporated, ionized, and incorporated in the plasma flow as well.

The processes associated with plasma generation and electron emission in the cathode spots are not clear even now. One possibility is a continuous transition from the solid phase to the plasma phase involving melting, evaporation, and ionization of the cathode material. The other is the explosion of microprotuberances with a direct sublimation of electrode material into the plasma phase.

At higher currents, the number of cathode spots increase and eventually merge to form a diffuse plasma region on the cathode (multicathode spot arc [MCS]). The emphasis of the research at Tel Aviv University has been to investigate MCS with pulsed peak currents ranging between 0.5 and 2 kA and pulse durations between 1 and 75 ms. Geometry determines the convection of plasma in the vacuum away from the cathode. In the case of no applied magnetic field, the ejection of plasma by the MCS, the geometry, and the mass conservation relations determine the deposition rate. The rate, which also depends on the biasing of the substrate, is highest when the substrate is the anode.

A substantial heat flux (associated with the recombination energy and the anode sheath potential drop) accompanies the material flux to the anode. In pulsed arcs used for coating applications, the heat loading can result in transformations of the surface by: promoting diffusion of the coating material into the substrate – allowing some degree of surface alloying – and forming metastable configurations on the surface that are quenched by heat conduction.

Tel Aviv has obtained so far (Boxman, 1986):

- Aluminization of steel
- Molybdenum coating on copper
- TiN coating of steel
- Quenching and cementation of steel
- Synthesis of molybdenum carbide surface alloys.

Summary and Conclusions

The research described in this report is addressed to the development of coating technologies which may be of large practical and economic significance. My impression is that, notwithstanding their practical importance, understanding of the physical processes occurring in MCS arcs is very limited. It is possible that application of the processes developed by Boxman may proceed without the need of a more detailed understanding. Should the use of these techniques become widespread, a detailed understanding of the flow of the cathode material and the entrainment of ambient atmosphere into the arc will be required to optimize the coating process. Such understanding may result from the application of the techniques that Professor Yitzhak Maron is developing at the Weizmann Institute of Science (Maron et al., 1988).

References

Boxman, R. L., et al., "Principles and Applications of Vacuum Arc Coatings," in *Proceedings of the XIII International Symposium on Discharges and Electrical Insulation in Vacuum*, Paris (1988).

Boxman, R. L., et al., "Fast Deposition of Metallurgical Coatings and Production of Surface Alloys Using a Pulsed High Current Vacuum Arc," *Thin Solid Films*, 139 (1986), 41-52.

Maron, Y. et al.,"Spectroscopic Investigations of the Non- equilibrium Plasma and the Charge Flow in Ion Beam Diodes," Paper AI3, in *Proceedings of the 7th International Conference on High-Power Particle Beams*, Karlsruhe, FRG, (1988), 57-68.

[See also pages 54-57, below.]

2/13

MATHEMATICS

A Mathematics Workshop: Theory and Practice of Geometric Modeling

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This meeting, held from 3 through 7 October 1988, brought together a somewhat diverse group of persons interested in geometric modeling. Principal interests of the participants varied from the mathematics of geometric modeling, to system development, to use of modeling systems. Consequently, the presentations covered a broad spectrum of topics of interest to persons involved in geometric modeling, including mathematical aspects of curve and surface representation, solid modeling, ray tracing of models, robotics, and database issues.

The organizer of the meeting was Professor Dr. Wolfgang Strasser of the Wilhelm Schickard Institut für Informatik at the University of Tübingen. The meeting was held at the Heinrich Fabri Institut Blaubeuren, a conference facility owned by the University of Tübingen and located in the village of Blaubeuren, west of Ulm, West Germany. Dormitories to house up to 70 persons, dining facilities, and meeting rooms make the institute self-contained for many meetings. There are additional hotel rooms available within walking distance in the village. This meeting attracted a somewhat larger attendance than was anticipated (about 100 persons) although considerably fewer were in attendance at any one time since many attended only the portion of the meeting devoted to topics in which they were particularly interested.

There were about 35 one-half-hour talks given. Since the meeting was a workshop, not all of the talks were polished lectures concerning completed work, and a number of talks were more in the nature of a prospectus for the future. There will be a proceedings of the meeting (Strasser and Seidel, 1989). I will describe some of the papers by general category.

Overview presentation

The opening talk, "Future Trends of Geometric Modeling: a Survey," was given by Michael Pratt (Cranfield Institute, UK). He addressed two principal topics, representation and communication. Representation is dependent on the user interface, so the two topics are not entirely independent. Free form surfaces, he said, can be of several types, here listed under increasing levels of constraints: aesthetic (no functional purpose), ductlike (for pipes or ducts), blends (which are boundary con-

strained), and fitted (having boundary and possibly interior constraints). Free form techniques include surface solid operations (e.g., intersections) and automatic blending of given boundary constraints by techniques such as projection, sweeping, lofting, and offsetting. Automatic blending is often carried out by repeated subdivision, such as when an approximate rectangular model is created, with the surface being completed by repeated subdivision. Filleting often gives complications when there are too many objects to be blended, although certain kinds of blending are easy to achieve, such as cylinder/plane blending. Cyclide surfaces, which include the quadrics, enable one to do simple blends within that type of representation.

Pratt said that communication must be thought of in several different ways. For the user of a computer-aided design system, communication (the interface) must be convenient and actions taken by the user must result in a predictable change to the design. As noted, the representation comes into play at this point. There are different types of interfaces necessary for the user. For example, there may be a static file to which the user cannot make changes, while certain aspects of the design may be changed by the user. Another problem is that of data interchange between various CAD systems. The representation of surfaces for various systems in current use range from representation by polynomials of degree up to 20, to nonuniform rational B-splines (the so-called NURBS). To complicate matters, other systems use solid models or wire frame models. To interchange data, there must be an agreed upon transformation between systems. Pratt said that, looking ahead to the future, advanced modeling systems will have the capability to allow interaction while maintaining certain constraints automatically. He thinks that the next few years will bring investigations into the best way of representing features of solid models.

Representation of Curves and Surfaces

About one-third of the papers presented were concerned with curve and surface representation. Hans Meier (consultant, Hamburg, West Germany) discussed "A Useful Polynomial Representation of Multiple Continuous Functions in the Unit Domain." Meier suggested a new set of basis functions for representation of polynomials. His basis has certain advantages similar to orthogonal polynomials, but is simpler to evaluate by recursion. The normalized basis for [0,1] is $f_0(t) = 1$, $f_1(t) = 2t\text{-}1$, $f_2(t) = 2t(t\text{-}1)$, and then $f_{2i}(t) = (f2)^i$ and $f_{2i+1}(t) = (f_2)^i f_1$, $i = 1,....$ Inner products are simple to compute (many of the basis functions and derivatives of basis functions are orthogonal with respect to the usual $L^2(0,1)$ inner product. Boundary conditions lead to a simple system of equations to be solved, and round off error properties are improved over the monomial basis. (It has been shown that the Bernstein basis is best in this sense.)

Klaus Höllig (Stuttgart University, West Germany) discussed geometric interpolation methods. He constructed a new parametric piecewise quadratic interpolation curve in space of class G^2 (second-order geometric continuity, in this case meaning continuity of the Frenet frame). He used the rational Bezier form since it simplified the conditions for continuity. Accuracy of the scheme is $O(h^6)$, which is obtained by using the geometric freedom to match geometric invariant. Höllig also gave a conjecture concerning the order of the error in a Taylor approximation for curves, which has been verified for low degree and dimension. The conjecture is that the order of the error of a degree k Taylor expansion in dimension d is

$$k\text{-}1 + \frac{k+1}{d\text{-}1}$$

"Geometric Programming: A Coordinate-free Approach" was the title of a discussion by Tony DeRose (University of Washington, Seattle). Matrix operations are used in CAD systems for a variety of transformations (on points, coordinates, and planes). DeRose contends that this leads to numerous possibilities for errors in the application of these transformations. By introducing a coordinate-free affine geometry he puts a layer of geometric abstract data types between the applications and the matrix work. In this way a geometrically unambiguous and valid system is obtained, where types cannot be accidentally mixed. The geometric objects consist of affine spaces (scalars, points, and vectors, with operations of vector addition, scalar multiplication,vectors from the difference of two points, and a point by adding a vector to a point). Data types are space, vector, point, and scalar. Procedures include space (name, dimension), vector addition, scalar multiplication, and so on. Frames (or coordinate systems) consist of an origin plus a basis. All this actually takes place in a"standard" frame which underlies the entire system. This scheme keeps spaces and points in those spaces together, and prevents confusing points from one space with those in another, since the system knows in which space each point lies. The paper's title is perhaps something of a misnomer, since everything is done with respect to the "standard" coordinate system, and thus is not truly coordinate-free. Nonetheless, the proposed system seems to give an added amount of protection to the user from himself, and the underlying coordinate system is transparent to him.

A review of geometric modeling of smooth surfaces using triangular patches was given by Hans Hagen (Kaiserslautern University, West Germany [a joint paper with Gregory Nielson of Arizona State University, Tempe]). The talk touched on many landmarks in the de-

velopment of triangular patches: barycentric coordinates; triangular Bezier patches; early work by Barnhill, Birkhoff, and Gordon, and by Barnhill and Gregory on Boolean sums and compatibility problems; convex combination surfaces and rational correction terms to achieve C^1 continuity; curvature continuous patches using a Geometric Hermite operator; and transfinite interpolation to values and normal derivatives on the boundary of a triangle. The talk concluded with recent work by Hagen on extending transfinite interpolation to include curvatures and the use of minimization of the integral of squared curvature to smooth surface patches.

J. Hahn (Daimler-Benz AG, West Germany) gave a talk titled "Filling Polygonal Holes with Rectangular Patches." When using rectangular patches for surface design, there are situations where patches with other than four sides are needed (e.g., three for a suitcase corner, five for an aircraft wing-body join). The suggested scheme is to subdivide the patch into four-sided subpatches by joining a central point to a point on the interior of each polygon edge. This gives a set of n rectangular patches for an n-sided polygon. It is impossible to construct such patches with parametric continuity; however, for design purposes geometric continuity is appropriate. The problem is at the central point and Hahn's solution lies in appropriately defining boundary data so that geometric continuity is achieved at the central point. Beginning with an assumption at one (interior) boundary for the patch, and working radially around the subpatches, it is necessary for the final patch to match the first. By putting the data along one radial edge in terms of the previous edge, a series of linear maps is obtained, from which it is then possible to obtain the identity map after passing entirely around the central point. The midpoint value is a parameter, and should probably be given by the designer, according to Hahn.

Ray Tracing

Ray tracing is a way of computing realistic graphical representations of objects or groups of objects. Two talks were concerned with the topic. Charles D. Woodward (Helsinki University, Finland) spoke on ray tracing parametric surfaces by subdivision in the viewing plane. Here the idea is to use bounding volumes (cubes or spheres) around each patch. Intersections of the ray with the bounding volume (call it a cell) is relatively easy to check, and with many cells there is a high probability that the ray will not strike a particular cell. However, each cell has to be checked, thus there is a trade-off between the number of cells and the complexity of the object within, against which the ray must be checked when the ray does intersect the cell. A uniform subdivision of the object or objects being ray-traced usually results in vastly differing number of objects in different cells. Woodward proposes to use a nonuniform subdivision either obtained by collapsing small cells together, or by initial construction. This complicates the searching process somewhat. During tests, small cells (fewer objects per cell) give better performance, due to fewer tests being required in a cell which is struck by the ray.

"Ray Tracing of Boundary Models with Implicit Blend Surfaces" was the subject of the talk by Panu Rekola (Nevanlinna Institute Helsinki, Finland [coauthored by L. Holmstrom, T. Laako, and M. Mantyla]). The basic problem in ray tracing is to determine which part of the scene is struck by a ray from the viewpoint of each pixel in the representation. In addition, it is necessary to account for light sources, shadows, and reflections. Ray tracing requires intensive numerical calculation to find intersections of the ray with the objects in the scene, for which the ray equation and the surface equation must be solved simultaneously. For certain surface representations this is a relatively simple process, but for surfaces made up of patches it is necessary to determine which patch (if any) the ray intersects. Rekola discussed a way of carrying out the process for parameterizable faces. The face is mapped into standard representation, and then mapped into the unit square. The intersection of the ray and the face are found and it is then determined whether the intersection is in the unit square. If so, the intersection is real; if not, the ray does not intersect that portion of the surface. For blended faces the implicit equation for the blending surface is treated by using bounding boxes. If the bounding box is pierced by the ray, further checks are necessary to see if the surface itself is actually encountered, as above.

Surface/Surface Intersections

Two speakers discussed the problem of computing surface/surface intersections. In general this involves nontrivial amounts of computation, as well as the difficulties of ensuring that all intersections have been found. The title of the presentation by Gabor Lukacs (Hungarian Academy of Sciences) was "The Generalized Inverse Matrix and the Surface/Surface Intersection Problem." He gave a review of the methods for surfaces defined in various ways (e.g., implicit with implicit, implicit with parametric, parametric with parametric). For the problem of the intersection of two parametric surfaces, $P = P(u,v)$ and $Q = Q(s,t)$, the (three-vector component) equation in four variables, $P(u,v)-Q(s,t) = 0$ must be solved along a path in parameter space. This leads to three equations in four unknowns, a fourth equation resulting from marching a certain step in the direction of the intersection curve. The scheme uses a arching method with the Newton iteration. Problems occur when surfaces have parallel tangent planes at an iterate point because in such cases the system for the Newton iteration is singular. Lukacs pro-

poses to use the generalized inverse in this situation. The geometric implication of using the generalized inverse is not clear, although it would seem to give a reasonable and stable way of moving off of the critical point.

The second speaker to address this intersection problem, Kuon-Ping Cheng (San Diego State University, California) titled his talk "Using Plane Vector Fields to Obtain all the Intersection Curves of Two General Surfaces." Cheng's goal was to find an algorithm which would do a successful global search for all local pieces of the intersection curve in a finite number of steps. His method uses the vector field, where each vector is given by the vector from each point on one of the surfaces to the closest point on the other surface, projected into the parametric plane. Intersection points are singular points of the vector field. Points of extreme magnitude (distance above and below the other surface – at least, on one side and the other of the first surface) can be used to find intersection curves. To do this one solves the differential equation whose solution is the curve through the vector field which connects extrema. This curve necessarily crosses an intersection curve, giving a starting point for finding that entire piece of the curve. By computing connecting curves between all (opposite) extreme magnitudes in the vector field, all pieces of the intersection curve must be crossed. This talk generated much discussion among the participants at the meeting. The consensus seemed to be that the principal difficulty with the scheme is the finding of all extrema in the vector field, perhaps no easier than the original problem.

Constructive Solid Geometry

Wayne Tiller (and coauthor D. Hook, both from SDRC, Milford, Ohio) discussed Boolean operations on 3-D objects defined as collections of trimmed surfaces. The unions, intersections, and cuts of 3-D objects using boundary representation by NURBS requires the calculation of intersection curves to "trim" the tensor product surfaces. Intersection curves have three representations: the actual curve in model space and two in the parameter spaces for the two intersecting surfaces. Intersection curves are represented by fitting them with piecewise quadratic curves. Tiller's algorithm consists of the following steps: (1) set up bookkeeping, (2) intersect untrimmed surface with each other, (3) trim and orient the intersection curves, (4) trace out new loops and form new faces, (5) check for inclusion of old faces in the new object.

Jerek Rossignac (IBM, Yorktown Heights) and Stephen Cameron (University of Oxford, UK) titled their talk "S-bounds and Active Zones in CSG." Rossignac observed that a lot of trimming is required in Boolean operations since there are often intersection edges which are not in the resulting object. Cameron mentioned such problems in connection with robot motion, and discussed the use of bounding boxes to decrease the required amount of testing for collisions. Intersection operations are performed for boxes which bound the object in question to obtain a final "box of interest," which is then intersected back with the primitives in the construction. Cameron called these objects S-bounds. The S-bounds can then be bounded by (possibly smaller) boxes, and the process repeated until convergence is obtained. Redundancies in the definition of the object are pointed out by empty S-bounds. According to Cameron, the process results in much less testing to obtain intersections, or to find there is no intersection.

"A Set Theoretic Solid Modeling System Based on Implicit Blends" was the title of the paper by Andrew Wallis (University of Bath, UK, [joint work with J.R. Woodwark of IBM UK Scientific Center]). The ideas he presented are a generalization of the curve scheme (conic blending) originated by Liming around 1940 (see Liming, 1979), for a reprint of the original book). A typical curve obtained by Liming in this fashion is of the form $(1-\lambda)AB + \lambda CD = 0$, where $A = 0$, $B = 0$, $C = 0$, and $D = 0$ are equations of lines in the plane. This results in a conic curve, and various choices of A, B, C, and D allow various shapes while coincident lines (e.g., $C = D$) enforce certain tangencies with the lines $A = 0$ and $B = 0$. If A, B, C, and D (= C) are replaced by half spaces, one obtains a blending half space. Several of these objects can be combined by set theoretic operations to obtain solid models. Wallis and Woodmark have created a special language in a modeling system called DODO, and are presently evaluating various aspects of the system, including spatial division, ray tracing for picture generation, and mass calculation properties.

M.A. O'Conner (and coauthor J. Rossignac, both from IBM Yorktown Heights) spoke on extending solid modeling techniques to higher dimensions. On first thought, solid modeling in more than three dimensions seems somewhat curious, but O'Conner pointed out that several applications, especially those involving motion and other time-varying processes, process simulation and planning, nonuniform material properties, and path planning for robotics could be more easily investigated. For example, in path planning for several (possibly interfering) robots, it is necessary to determine a way to move the robots around to get their task done without collisions occurring with fixed objects, or with each other. The standard algorithms are incremental, swept-volume methods. By modeling the object in four dimensions (space and time) one can check for intersections of the 4-D models. The same ideas can be used in different contexts; for example, if material is being deposited on two separated objects (so they are growing), when will the two objects contact each other? O'Conner recalled the several areas which contribute to the ideas involved in solid modeling

and discussed the decomposition of such objects into lower dimensional boundaries.

Containment Algorithms

Professor Ralph Martin (coauthor P.C. Stephenson, both from University College, Cardiff, UK) spoke on containment algorithms for objects in rectangular boxes. The problem is to determine whether a given object will fit into a given rectangular box. Fortunately the problem is the same as for the convex hull of the object, which simplifies things somewhat. The problem is solvable for a quadrilateral object, and this can be used to solve the problem for an n-gon, since only four vertices (the active vertices) matter at one time. There may be a lot of checking to do, however. Objects which have curved edges present problems because the active points on the boundary are more difficult to find. A related problem is finding the box of minimum area into which the object will fit. It is known that one edge of a polygonal object must fit along the one edge of the box, which greatly simplifies the problem. Other such problems, about which less is known, include finding the box of minimum perimeter, and finding the box of minimum height for a given width. For the latter problem it is assumed that the object will fit in some box satisfying the given dimension. Three-dimensional problems are considerably more complicated. For polyhedrons there would be six active vertices and two rotations to be considered.

Database and Data Handling Issues

Several speakers discussed topics concerned with how data for the definition of objects is stored, retrieved, and converted to other systems. These talks included the following:

- Jean-Marc Brun (Coretech International, Les Ulis, France), "Solid Modelling Schemes, Conversion and Solid Reconstruction"
- E.G. Schlechtendahl (coauthors E. Trostmann, U. Kroszynski, and B. Palström, Nuclear Research Center, Karlsruhe, West Germany), "Neutral Interfaces for Communication of Geometry Information"
- Per Evensen (Center for Industrial Research, Oslo, Norway),"Experiences Using Adjacency for Building Topology Structures"
- Ch. Hubel (coauthors T. Härder and B. Mitschang, Kaiserslautern University), "Information Structures and Database Support for Solid Modelling"
- S. Rude (coauthor H. Graowski, Karlsruhe University), "Intelligent CAD Systems Based on Technical Associate Modelling"
- M. v. Emmerik (Technical University Delft, Netherlands), "A System for Graphical Interaction on Procedural Models"
- N. Yaramanoglu (coauthors F.-L. Krause, M. Bienert, F. Vosgerau, IPK, Berlin, West Germany), "A Feature Oriented System Design for Geometric Modelling"

Conclusions

This meeting was quite successful in bringing together workers in different areas related to geometric modeling. There was ample time for discussion of the ideas presented, and such discussion was facilitated by the family-style meals served and the almost exclusive use of the center by the attendees at the meeting. I hope this will be but the first of a series of such meetings.

References

Strasser, W., and H.-P. Seidel, *Theory and Practice of Geometric Modeling*, (Springer, 1989).

R. A. Liming, *Math for Computer Graphics*, (TAB Books, 1979).

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Numerical Analysis in the Department of Computer Science at Katholieke Universiteit Leuven

by Richard Franke.

The Katholieke Universiteit Leuven (KU Leuven) is a very large university situated in and around Leuven, Belgium. My visit to the Department of Computer Science was arranged through Professor Paul Dierckx. The Computer Science Department occupies part of a modern building situated on one of several quadrangles of buildings on the outskirts of Leuven, in Heverlee.

Spline Approximation

Professor Dierckx has been working in the general area of spline smoothing in one and more dimensions, and developing Fortran software for this purpose for several years. His work has culminated in a subroutine package, FITPACK (Dierckz, 1987), which is available electronically through NETLIB. The package contains routines for fitting with splines of specified degree and end conditions. Automatic smoothing is possible and can be carried out with various conditions such as closed curve and derivative constraints, as well as convexity constraints. Applications subroutines for finding derivatives, integrals, Fourier coefficients, or roots are included. Some of the algorithms have also been made available in commercial subroutine packages. Knot insertion into existing spline curves can be carried out. The directions of his future work are likely to be toward computer-aided geometric design, which is where knot insertion algorithms are often very useful. In addition to the curve fitting work mentioned above, he has published papers concerned with spline fitting of scattered data in two dimensions and on the sphere.

Numerical Integration

Another somewhat conventional area of work at the university is under the direction of Professor Ann Haegemans. This work is concerned with the theory of multidimensional quadrature formulae, but with a new and modern slant that should find many applications throughout scientific computing. The work is, in part, being carried out by two doctoral students, Ronald Cools and Marc Beckers. Cools is studying the problem of embedded families of two-dimensional quadrature (or cubature) rules. Such rules are useful for the automatic evaluation of definite integrals. In such applications one rule is used to estimate the integral while the other is used to obtain an estimate of the error in the approximation. There are several possible approaches to the problem. One is purely algebraic and leads to a large system of nonlinear equations, which one must then attempt to solve for the weights and nodes of the cubature formula. This can and has been carried out successfully for a large number of rules of not too high of a degree (a formula is of degree d if it is exact for all polynomials of degree d or less, but not exact for all polynomials of degree $d+1$).

The assumption of symmetry for the region (including the weight function) and the formula lead to a reduction in the number of equations. Through the use of orthogonal polynomial theory and polynomial ideals, one can hope to reduce the size of the systems of equations, but there are possible problems with common roots which do not lie in the region of integration (unlike the one-dimensional case, which has a much cleaner theory).

Recent work by Cools and Haegemans has resulted in an algorithm for computing families of embedded cubature rules with positive weights (Cools and Haegemans, July 1988). For automatic integration purposes it is advantageous to have the degrees of the two formulas differ by only a little, and their work is toward formulas of degree 2m + 1 and 2m-1. The algorithm starts with a known cubature formula and then finds a formula using a subset of the nodes, which is of lower degree. This can continue until only one point is left and the degree of the formula is zero or one. In related work Cools and Haegemans have given lower bounds on the number of nodes required by embedded cubature formulas in several dimensions (Cools and Haegemans, June 1988). These lower bounds are almost certainly not sharp (cannot be attained), and in spaces of dimension up to 5 or so the known formulas tend to have some excess nodes -- up to several times as many nodes as the lower bound they give.

Beckers and Haegemans have been working on the construction of cubature rules for the three-dimensional case. The use of symmetry of the region of integration reduces the number of equations to be satisfied. They have computed rules of degree up 13 for the cube, sphere, and all of three-space with certain weight functions (Beckers and Haegemans, March 1988). For degrees up to nine the formulas are usually already known, but the formulas for degrees 11 and 13 are new. Current work is toward extending the three-dimensional work to computing embedded cubature formulas. One problem they are struggling with is that for adaptive cubature the most useful formulas would seem to be for simplices (triangles and triangular pyramids), and the most useful techniques for construction of formulas are hard to apply to this case, although they have had some success.

Minimal Partial Realization

I talked with Dr. Marc van Barel and his advisor, Professor A.Bultheel, about their work in minimal partial realization. The problem is that of determining matrices G(z) and A(z) such that

$$\sum_i M_i z^{-i} = G(z)A(z)^{-1} + O(z^{-N-1}),$$

where the M_i and G(z) are pxn matrices with entries from a finite field, and A(z) is nxn, again with entries from the finite field, and it is desired to make det(A) of as small degree in z as possible. The problem is related to that of Padé approximation in the matrix sense in a finite real field, and can also be interpreted in terms of continued fractions. The applications of the work are in approximating a given transfer function and in inverse scattering problems in layered media (in geophysics, for example). The technique has been used in the scalar case in speech recognition. The results include a computational algo-

rithm written in Ada to make it easy to alter the finite field in which the approximation takes place. Von Barel will be spending 3 months at the Naval Postgraduate School, Monterey, California, conducting joint work with Professor William Gragg. This travel and research is supported by a grant from the Belgian government.

Algorithms for Intel iPSC/2 Hypercube Computers

A significant effort in learning how to use hypercube computer architectures is taking place at KU Leuven. The work is being performed on a 16-node, 4-MB per node, Intel iPSC/2 – the first to be installed in Europe. This machine replaced an earlier version of the Intel machine. While the work is being performed on the Intel machine, it has obvious carryover to other parallel local-memory machines. The project began in 1985, when there were two or three people in the group. Beginning in October 1987 a research project, "Parallel Numerical Algorithms," was funded by the Belgian Government for a total of about $1 million. There are now seven persons involved in the project working in numerical analysis. In addition, the group cooperates with other groups using the hypercube. These groups (whom I was unable to visit) are concerned with distributed systems and image processing. Master's theses have also been written at KU Leuven on parallel ray tracing and VLSI circuit simulations.

Familiarization. The initial work was concerned with gaining experience with the hypercube. The original machine was apparently somewhat user unfriendly, but according to reports of the workers this has been vastly improved with the iPSC/2, which they now consider to be reasonably friendly. L. Beernaert, K. De Staercke, and D. Roose began the work (which in some cases is continuing) concerned with linear algebra problems and a library for solving elliptic pde's. The work here is mainly concerned with solving systems of equations by the usual methods, including Gaussian elimination for banded systems, QR factorization of dense matrices, substructuring methods, iterative methods such as Jacobi, SOR, preconditioned conjugate gradient, and multigrid methods for pde's.

Elliptic pde's

An extensive investigation and comparison of several methods for the solution of an elliptic equation was carried out by S. Vandewalle and J. De Keyser. The equation was discretized using the five-point approximation to the Laplacian. The problem was partitioned into a 2x8 (overlapping) array for distribution to the processors. Depending on the iterative solution method chosen, several communication problems have to be solved. The results are detailed in a preprint (Vandewalle et al., preprint).

Jacobi Method. For this method, information computed by other nodes needs to be communicated to neighbors only after the completion of the iteration. In order to maximize overlap of communication and computation, iterates for the boundary nodes (for each processor, not the problem) are computed first, and communication initiated while the rest of the computation proceeds.

SOR. Here a red-black ordering is used and the iterates for all nodes of one color are computed first. Again, the iterates for each processor's boundary nodes are computed first, and communication to the neighboring processors is initiated while the remaining computation is completed. The process is then repeated for the other color nodes. Because of the startup time associated with communication, total communication time is increased over the Jacobi iteration, although the convergence is sufficiently faster to make up for it on reasonably large problems.

Preconditioned Conjugate Gradient. In the current version of the project, a simple diagonal preconditioner is used. The equations associated with gridpoints in the domain of each node are stored in the memory for each node, making matrix-vector multiples possible without communication. Scalar products are computed using the usual treewise process, obtaining the result in processor zero, which is then communicated to all nodes. This method was generally much slower than SOR and multigrid methods.

Multigrid. This method has several problems to overcome in terms of communication and load balancing. The domain of the problem is again partitioned among the processors. The individual multigrid operations (smoothing, defect calculation, restriction, and prolongation) are all pretty nicely parallel. The principal problem occurs when some of the processors are inactive on the very coarse grids. These processors cannot compute the interpolated values at their finer grid points since the needed coarse grid values are not available to them. This is handled by having the values computed by the neighboring processors. Receipt of these values by the inactive processors revives them. The processor-idling problem is a major one and seriously degrading the performance of the system on the coarse grids. Several ideas for alleviating the problem will be investigated, including decreasing the number of times the coarse grids are "visited" and applying different partitioning strategies. Even with the degradation of the potential of the multigrid scheme, it was still by far the fastest method for a 127x127 grid.

Other Investigations Using the iPSC/2

Waveform relaxation methods for time dependent pde's. S. Vandewalle and R. Piessens are investigating

these methods, originally developed to solve systems of ode's, and their solution on the hypercube. Multigrid methods are being incorporated into the solution, and comparisons with classical and other solution methods will be undertaken.

Domain decomposition methods for pde's. D. Goovaerts and R. Piessens are studying domain decomposition schemes. Both overlapping and nonoverlapping techniques are being considered, leading to Schwartz and Schur-complement methods. The applicability of preconditioners is being studied. An equivalence between the Schwartz and Schur-complement method has been established.

Parallel algorithms for continuation and bifurcation analysis of nonlinear differential systems. D. Roose is studying the application of the hypercube to solution of continuation and bifurcation problems. These problems lead to complications such as loss of symmetry and indefiniteness, unlike the usual model problems. He is studying the implementation of a multigrid continuation algorithm on the machine.

Image processing algorithms for local-memory multiprocessors. H. Embrechts and D. Roose are studying algorithms for image processing. They are primarily concentrating on parallel algorithms on a medium level, such as component labeling and finding convex hulls. A considerable problem here is load balancing since the amount of work depends on the components in the part of the picture assigned to a particular processor. Some effort is being spent on the initial decomposition of the image for distribution to the processors, although redistribution of the load will probably have to occur dynamically.

A simple demonstration of dynamic load balancing, in the mold of image processing, was shown. A "perfectly parallel" problem, that of generating and plotting a Mandelbrot fractal set, was first shown without load balancing. The domain was divided into same-size rectangular subsets, one for each processor. The amount of work depends on the number of "dark" pixels. Thus, certain processors finished very rapidly, while others had a great deal more work to do, the slowest determining the time to complete the problem. A simple load-balancing procedure is for a node which has completed its work to obtain half of the remaining work from the nearest neighbor that is still active. This results in a nice reduction in the total problem time. A somewhat more complicated algorithm for division of work could reduce the total amount of communication needed to complete the problem. In computations requiring significant communication to dynamically reassign part of the problem, this would be more important.

Deadlock detection on local memory multiprocessors. Deadlock detection is being studied by Y. Berbers and W. Joosen. Deadlocks can occur with multiple processors when each of two need resources held by the other processor in order to continue, but neither will release the held resource. Considerably more complicated deadlocks can occur. Presently there is no deadlock detection on the iPSC/2, and, of course, there is no way of resolving them. The results of this study are to include the implementation of deadlock detection on the iPSC/2.

Visualization of iPSC/2 Performance

A project just being contemplated is that of using a high-performance workstation connected to the iPSC/2 to monitor the performance of the machine during execution of a program. This work is being supported by IBM through the loan of an IBM RT PC workstation. The idea is to develop a "graphical" debugger, which will give real-time graphical information about how the computations are proceeding, such as the efficiency of each node and information about why a node is idle when it is. This information can be very useful, for example, in load balancing. This kind of information can be made available at present, but like many other situations, is not presented in a manner that is easy to interpret. Use of the workstation should allow instant replays of the information, as well.

Conclusion

Researchers at the Katholieke Universiteit Leuven are involved in a number of different aspects of mathematical and algorithmic developments. The work in numerical integration is at the forefront of the theory. Development of high-quality mathematical software is very important, although traditionally not much recognized as a suitable endeavor for tenure track personnel at a university level. It is possible this may change in the future as there is no doubt it is very demanding in terms of time and logical thought processes. The work on the iPSC/2 treats a broad range of algorithmic topics. I believe this work will become an important contribution to the knowledge of how local-memory multiprocessor computing systems can be efficiently used to solve scientific problems.

References

Beckers, M. and A. Haegemans, "The Construction ofThree-Dimensional Invariant Cubature Formulae," *Report TW* 85, Katholieke Universiteit Leuven, Department of Computer Science, November 1986, Revised March 1988.

Cools, R. and A. Haegemans, "On the Construction of Multi-Dimensional Embedded Cubature Formulae," *Report TW* 112, Katholieke Universiteit Leuven, Department of Computer Science, July 1988.

____, "A Lower Bound for the Number of Function Evaluations in an Error Estimate for Numerical Integration," *Report TW* 111, Katholieke Universiteit Leuven, Department of Computer Science, June 1988.

Dierckx, P., "FITPACK User Guide, Part 1: Curve Fitting Routines," *Report TW* 89, Katholieke Universiteit Leuven,Department of Computer Science, March 1987.

Vandewalle, S., J. De Keyser, and R. Piessens, "The Numerical Solution of Elliptic Partial Differential Equations on a Hypercube Multiprocessor," (preprint).

12/14/88

The Mathematics of Surfaces - an International Conference

by Richard Franke.

This meeting, held at the University of Oxford from 15 through 21 September 1988, was sponsored by the Institute for Mathematics and its Applications, a British society based in Southend-on-Sea. It was the third in a series of biannual meetings. Proceedings of the previous two are available and the proceedings of this meeting will be forthcoming (Hanscomb, 1989). The main thrust of the meeting was in the area of mathematical representation of surfaces for computational purposes. The applications range from computer-aided design and manufacture to numerous scientific fields such as engineering, medicine, and cartography and to film and television. In addition to surfaces, there was also great interest in curves and solid modeling. Attended mainly by British experts, the meeting included 11 invited talks of 45 minutes each, and 14 contributed talks of 30 minutes each. There were no parallel sessions. For purposes of discussion, the areas treated by the talks will be grouped, and the more interesting/important results discussed in some detail.

Surface Representation

A survey talk, titled "Circles and Cyclides," was given by Dr. Malcolm Sabin, FEGS, Ltd. (Cambridge, UK). The talk concerned his work in various types of geometry and how they fit together (or not, as the case may be). Even though the several points of view may be valuable to those working in computer-aided geometric design (CAGD), he pointed out the gulf between them by noting, for example, that the differential geometer assumes that curves can be parameterized in terms of arc length, but the algebraic geometer asks "What is arc length?" Between projective geometry (planes transform into planes) and metric geometry (distances remain fixed under transformations) lie affine geometry (planes transform to planes, and infinity remains at infinity) and similarity geometry (angles remain fixed under transformations). Differential geometry (having to do with properties in the small) and algebraic geometry (concerned with properties in the large of geometric forms described by algebraic functions) are quite different. The point of view one wants to take depends on the important properties to be preserved and on understanding the "absolutes" – that is, what happens to the invariants in one geometry as one moves to a more restrictive class. Cyclides are a class of quartic surfaces which include many of the surfaces of prime interest to manufacturers – planes, natural quadrics, spheres, right circular cylinders and cones, and the torus. They have a number of interesting and useful properties. One of the more useful properties is that the offset of a cyclide surface is also a cyclide (as a contrast, it was pointed out by Farouki [see below] that the two offsets of a parametric plane curve of degree 3 can be defined as an implicit equation of degree 10). Intersection curves are also simplified for cyclides, since they may be parameterized as fourth-order curves, although in general two quartics will intersect in an order-16 curve.

Another discussion of cyclides was given by Professor M.J. Pratt of the Cranfield Institute (UK) in his talk, "Application of Cyclide Surfaces in Geometric Modeling." Cyclides are implicit surfaces, and one of their more useful geometric forms is a distorted torus – that is, a torus whose (necessarily circular) cross section varies as one goes around the "doughnut." It can be easily parameterized, which is an important property. The curves of constant curvature are circles. A cyclide patch is taken to be the surface defined for the parameter values within a certain rectangular region. There is a rational Bezier form for the patch, so it can easily be incorporated into any surface modeling system that uses this representation. As noted above, offsets for cyclide patches are also cyclide patches, and further, the patch boundaries are unchanged. Pratt also discussed the use of cyclides for blends in solid modeling, but here the situation is not so satisfactory, although a smooth cyclide blend between a plane and an inclined cylinder is possible.

Professor C. L. Bajaj, Purdue University (Indiana) discussed geometric modeling with algebraic surfaces. He said in the representation of surfaces there is always the question of whether it should be by parametric equa-

tions – i.e., each coordinate represented as a function of parameters (three coordinates and two parameters in the case of three-dimensional surfaces), or as an implicit function, which for the case of a three-dimensional surface is of the form f(x,y,z) = 0. Bajaj said that for certain operations which are often done in CAGD, such as intersections of surfaces, it is advantageous to have both representations available for at least one of the surfaces. This leads to the question of whether an implicitly defined surface can be parameterized, and vice versa. It is also of importance to have the parameterization be rational (that is, each coordinate of the parameterization is a quotient of polynomials in the parameters). In general the algorithm for this is known for implicit surfaces up to degree *n* in *n* space, which for most purposes means up to degree 3. For the opposite transformation, rational parametric curves/surfaces can in theory be expressed as implicit functions through the use of resultants; however, the degree of the equations tends to be so large as to be impractical. In order to achieve the desired practical results needed here it is necessary to combine ideas from a number of areas as diverse as algebraic geometry, computer algebra, computational geometry, and numerical approximation theory. Few persons have the necessarily diverse training to make significant contributions. Bajaj gave a list of areas in which he feels more work is needed: area and volume computations; surface and volume mesh generation; display and animation of surfaces; geometric languages and editing capabilities; interpolation, approximation, and continuity; and parallel algorithms.

A paper on parametric blending in a boundary representation solid modeler was presented by Dr. Tamás Várady of the Hungarian Academy of Sciences (coauthors: J. Vida, and R. R. Martin of University College, Cardiff, UK). The paper discussed various ways of blending two surfaces to obtain a smooth transition between the two. Blends may or may not be a vital part of the design, may have implicit or explicit representation, and can be of various types, such as constant radius or varying radius circular arcs, free form, and varying radius. Varady discussed the blending done in the Hungarian solid modeler (called FFSOLID). The system uses a so-called "double quadratic" representation of curves and surfaces, giving a slightly simpler scheme than cubics, having the same freedom but with a loss of smoothness. The blends used in the system are local operations, and have an explicit representation. More information about the use of the double quadratic representation was given, indicating that the problems of parameterization, least squares fitting, tolerance tests, and adaptivity are similar to those encountered when other systems are used. It is possible to fit with both positional and tangential information given along with the specified tolerances.

Numerical Aspects of CAGD

The numerical aspects of CAGD have often not been given adequate consideration. Indeed, many of the contributors to the science are products of computer science departments who often have scant training in numerical analysis and the vagaries of floating point arithmetic.

Dr. R. T. Farouki of IBM's Watson Research Center (Yorktown Heights, New York) spoke on numerical stability in geometric algorithms and representations. He has been investigating the condition number (essentially the largest ratio possible between the amount a quantity changes due to a small perturbation in a parameter and the perturbation in that parameter; put another way, a quantity may be perturbed by as much as the condition number times the perturbation in the parameter). The particular formulation of the problem may have a very large effect on the condition number. One example is the use of the usual power form for evaluation of polynomials versus the Bernstein-Bezier form. As a special instance, Farouki noted that with its 20 equally spaced roots transformed to lie at $\frac{1}{20}$, i = 1,...,20, the notorious Wilkinson polynomial has condition numbers for some roots as big as 10^{13}. When expressed in Bernstein-Bezier form, the condition number is relatively milder at around 10^{6}. It should be noted that the Bernstein basis involves only positive functions and, more importantly, that the Bernstein-Bezier functions satisfy a convex hull property. Further, Farouki has shown that the Bernstein-Bezier basis is optimal. There is no free lunch, of course. Converting from power basis to Bernstein-Bezier involves a condition number which is the ratio between the two. The point is that many CAGD systems use the Bernstein-Bezier basis for representation, but have often converted to power basis for evaluation. Since one never gains in the conversion process, it follows that evaluation should also be done in the Bernstein- Bezier basis. The use of backward error analysis (also pioneered by Wilkinson) may prove to be very fruitful in this area.

Interpolation and Approximation

The presentations brought out a number of developments regarding interpolation and approximation of surfaces, involving univariate data as well as multidimensional data, both gridded and scattered. A class of methods known as radial basis function methods have been used for more than 15 years to interpolate scattered data. In its simplest form, it can be easily described. Suppose data points (xk,yk,fk), k = 1,...,N are given. Let $\Phi(d)$ denote a univariate function. Then form the sum

$$F(x,y) = \sum_{k=1}^{N} A_k \Phi(d_k),$$

where d_k is the Euclidean distance from the point (x,y) to the point (x_k,y_k), and determine the coefficients A_k so that the function F(x,y) takes on the value f_k at the corresponding (x_k,y_k). The basis functions for the method are "radial" functions centered at the data points. This scheme was put forward by R. L. Hardy with $\Phi(d) = (d^2 + r^2)^{1/2}$, and in this context is called multiquadric interpolation. Until the past few years, very little was known about the theoretical aspects of this class of methods (with exceptions for certain Φ), not even whether it was always possible to find the coefficients A_k (equivalent to the nonsingularity of the matrix $\{\Phi(d_{kj})\}$, where d_{kj} is the distance between the data points k and j). No counterexamples were known, and from numerous practical applications and simulations, it was known that certain of schemes, especially the one proposed by Hardy, had excellent approximation properties. In the last few years there have been many theoretical developments, and these were discussed by two speakers.

I.R.H. Jackson, University of Cambridge (UK), presented a paper titled "Radial Basis Functions – A Survey and New Results." Jackson mentioned that Micchelli had proved general results, showing that many functions Φ lead to nonsingular systems, perhaps with a slightly modified form of the interpolation function which had the effect of building-in polynomial precision for the method as well as making the modified matrix nonsingular. For large numbers of points (depending on the disposition of the points, 200-300 seems to be a popularly quoted number) the problem becomes computationally intractable. Jackson also reviewed the results of Dyn and Levin and others on preconditioning which leads to a system amenable to treatment by iterative methods. Finally, he gave the results that he and Buhmann achieved concerning convergence of quasi-interpolation functions arising from radial basis functions. Quasi-interpolation is approximation by linear combinations of basis functions similar to that above, where the A_k are taken to be the f_k but the basis functions Φ are replace by linear combinations of the $\Phi_k(= \Phi.(d_k))$ While these results are for the equally spaced (infinite data) case, rates of convergence of surprisingly high order are obtained and are noteworthy in several respects. First, convergence of such schemes show the approximation power of the particular classes of functions. Although the basis functions are not polynomials, certain of the schemes do have polynomial precision. Also very interesting are the specific details of some of the results, which show that the multiquadric method possesses convergence rates greater than obtained with other basis functions which seem, at initial glance, to be more suitable. Here I am referring to the fact that multiquadric functions grow (asymptotically) linearly with distance from the data point they are associated with, while other proposed basis functions such as reciprocal multiquadric functions, decay with distance. Nonetheless, it has been shown that there are no linear combinations of the reciprocal multiquadrics suitable for quasi-interpolation in low dimensions, and that the rate of convergence is greater for the multiquadric quasi-interpolant than for the reciprocal multiquadric quasi-interpolant in any case.

Related ideas in a paper titled, "Fast Quasi-Interpolation of Surfaces with Generalized B-Splines on Regular Nets" were presented by C. Rabut of Université Paul Sabatier (Toulouse, France). B-spline approximation is conceptually similar to quasi-interpolation where the Φ_k are B-splines. Replacement of the B-spline basis functions by those obtained by application of discrete versions of the iterated Laplacian operator applied to B-splines results in functions which are larger near the node at which they are centered, and thus yield closer approximations to the given data. This process applies equally well in any dimension, provided the data is on a grid. The work is related to that of Dyn and Levin.

On a somewhat different topic was the work presented by K. Unsworth (coauthor, S. Asadiroyan), University of Dundee, UK, "Shape Preserving Surface Interpolation." Here the method assumes that the data is gridded, and along grid lines the data is consistent with an underlying function that is monotonic or convex in coordinate directions. The object is to preserve these properties in a smooth interpolation function. (In addition to the univariate case, there is previous work in the bivariate case by Carlson and Fritsch, and Beatson and Ziegler.) For the monotonic case, the approximating surface is a piecewise biquadratic function, with a 2x2 subgrid in each grid rectangle, expressed in the Bernstein-Bezier form. The first partial derivatives and the cross partial derivatives at the grid points are parameters to be determined. Use of the Bernstein-Bezier basis simplifies looking at the inequalities that necessarily must be satisfied in order to attain monotonicity throughout the grid rectangle. Three sweeps through the grid are required to determine suitable partial derivatives. For convexity the situation is more complicated, with a 3x3 subgrid being required, and, in addition, the locations of the subgrids are also parameters to be determined, along with the partial derivatives at the grid points.

"The Approximation of Hydrographic Survey Data with Tensor Product B-spline Surfaces" was the lecture given by B. L. MacCarthy (coauthor, D. C. Handscomb), University of Oxford (UK). The problem is to obtain a functional representation for the ocean depth over a large area from depth soundings for use in an experimental navigation system. These measurements are subject to error and are irregularly spaced. The approximation must be capable of being evaluated rapidly since both value and derivative are needed in real-time computations. Tensor product B-splines satisfy those requirements, but the placement of knots and overall

approximation strategy had to be investigated. Least squares methods have been used (see Cox, 1982), but are numerically expensive to compute (irrelevant in the final use) and frequently lead to rank deficiencies in areas where data is scarce. The approach eventually judged better by MacCarthy and Handscomb was a two-stage process where a grid was specified and a local scattered data interpolation method used to obtain function values on the grid – these data then being fit with the tensor product splines. Related work here has been performed by Foley.

When transferring data between CAD systems using different representation schemes for curves and surfaces, a transformation must be undertaken. A certain accuracy must be achieved without unduly increasing the amount of data for the representation. Addressing this problem was the talk by R. J. Goult of the Cranfield Institute of Technology (UK), "Parametric Curve and Surface Approximation." He discussed two techniques developed at Cranfield. The first uses constrained Chebyshev polynomials to perform Chebyshev economization while preserving the endpoint conditions. An error estimate is provided for various end conditions that can be chosen. The second method uses constrained Chebyshev approximation to construct polynomial approximations of any required degree. Unlike the first method, this method can be used whether the original representation is polynomial, rational, or other type of parametric representation. Related work has been carried out by Lachance.

Patches

Surfaces are generally represented by parametric patches, and several talks were concerned with the definition and manipulation of patches. Two of the talks treated the construction of multisided patches.

Dr. H.-P Seidel of Universität Tübingen, West Germany, gave a talk titled "A New Multi-Affine Approach to B-splines." The fact that symmetric p-affine maps and polynomials of degree p are equivalent, Seidel said, leads to new and shorter proofs of known principles in B-spline manipulations, such as polynomial precision, knot insertion, and the variation diminishing property. This new approach simplifies certain aspects of the theory, and the generalization to triangular B-splines should follow. It remains to be seen if the approach can yield new results.

The second talk was delivered by Ms. V. Skytt (coauthor, M. Dæhlen) of the Senter for Industriforskning in Oslo, Norway. She discussed the modeling of nonrectangular patches using box-splines. Box splines are a special type of multivariate spline defined on a uniform mesh. In this case the application is with splines defined on a three-direction triangular mesh. Using linear combinations of translates of these splines, the authors construct three-, four-, five-, and six-sided patches. Polygonal patches are needed in a variety of applications, such as wing-body joins and suitcase corners, and in general must be joined with triangular or rectangular patches. Joining a B-spline patch with an existing box spline patch presents no particular problem. Because of the the uniform nature of the box spline patch, it is not always possible to exactly join with an existing B-spline patch, and the authors propose to do this by least squares and data reduction methods.

Another paper treating the same problem in a different way was that of Dr. G. Renner of the Hungarian Academy of Sciences. In his work the idea was to divide an n-sided patch into four-sided patches through the introduction of a central point which serves as a vertex for all of the resulting subpatches, along with midpoints of the original boundary segments for the patch. The basic problem then is appropriate specification of the normal vector at the central point and midpoints, and the patch boundaries. Some alternative choices were discussed.

Solid Modeling

Shapes can sometimes be conveniently modeled using some primitive forms and Boolean operations on them. This is sometimes called constructive solid geometry (CSG), and the primitives are generally described as implicit algebraic inequalities. Two papers were given in this area.

A paper from the Unversity of Leeds (UK) given by A. Saia (coauthors, S.E. Howe, M.S. Bloor, and A. de Pennington), discussed sculptured solid shapes using inner and outer bounded models. The paper described the problems of bringing in the richer set of primitives needed for sculptured modeling in their quadric-based modeler at Leeds. This is being done through a scheme called ISOS (inner set outer set). The outer set completely contains the object, and the inner set is completely contained in it. A recursive subdivision technique is used. Because the intersection of two bicubic surfaces is (in general) a curve of degree 324, piecewise linear functions are used in the approximations.

The paper by A. Bowyer (coauthors, A.F. Wallis, J.H. Davenport, P.S. Milne, and J. Padget) of the University of Bath (UK), titled "The Use of Symbolic Computation in Geometric Modelling" addressed these issues. In using CSG the complexity of the objects being modeled leads to rather complicated descriptions, through an object having many bits and pieces as well as through the shape. Interrogation of a solid model about whether points are inside or outside the object, intersections, volume calculations, and so on are often required. It discussed the authors' work in classifying high-degree implicit polynomial inequalities against rays and boxes. An extension of Descartes' rule of signs is used (due to PSM) and is high-

ly efficient. However, exact arithmetic is required, and the investigation is pursued using the Reduce symbolic algebra system.

"Swept Volumes in CSG and B-rep Solid Modelers" was the title of the talk given by R.R. Martin (coauthor, P.C. Stephenson) of University College, Cardiff (UK). This paper was a review of sweeping techniques in solid modeling systems. A three-dimensional (3-D) object may be created by sweeping a 2-D object, or the volume occupied by moving a 3-D object (e.g., a robot arm, or the wheel in a wheel well) may be of interest. A large number of problems are potentially of interest here, including the general theory, how these shapes can be combined with others in the model, self-intersections and implications of these, the silhouette curves, and computational aspects.

Robotics

A. Blake of the University of Oxford discussed "Visual reconstruction of surfaces in robot vision." The object of such work is to reconstruct piecewise continuous functions from intensity distributions from a television camera, depth data from stereoscopic images, or other data. Blake said that the approximations used are often based on physical analogies such as nonlinear elastic sheets. These functions minimize a certain functional involving fidelity to the data and some behavior of the surface (such as a tension parameter). One often wants to automatically detect edges in the image, for which the nonlinearities allow. Other models are statistical, related to filtering, Blake said, and there is a connection between the two.

A sculptured surface approach using diffusion smoothing was the subject of the discussion by Li-Dong Cai of the University of Edinburgh (UK). For given raw data – for example, laser range data – one wants to reconstruct the surface image. A relatively cheap (computationally) algorithm is desirable. Cai prefers a data-data approach to avoid any parametric form. Such an approach has been used previously by Gaussian smoothing, wherein the surface is repeatedly smoothed by convolution with a Gaussian kernel on a 3x3 mask. Cai proposes to do a similar smoothing, but using a kernel related to the diffusion equation. He noted several advantages over Gaussian smoothing, as well as a certain kind of equivalence. The process is somewhat suspicious from a theoretical point of view, since the quantity being minimized seems to be the functional corresponding to Laplace's equation, which does not have finite solutions under point loads. As a practical matter, others have apparently also obtained satisfactory results with similar schemes.

Other

Professor R. E. Barnhill of Arizona State University, Tempe, gave a survey talk on geometry processing of surfaces. He cited examples to demonstrate that various attributes of a surface (after it is constructed) may be needed, such as offsets, intersections with other surfaces, and physical properties such as volumes and surface areas. He discussed work in progress at the university on these topics and the use of graphics, illustrated by a slide presentation.

The integration of intensive numerical calculation with graphics visualization was described by T. David (coauthors, P.H. Gaskell and A. Saia) of University of Leeds in his talk, "Integrating Sculptured Surface Design with the 'Panel Method' for Flow Visualisation." The problem he considered was that of 3-D flow around complex bodies. The panel method, a linear inviscid approximation to the Navier-Stokes equations, was used for the numerical approximation; the surface of the body was modeled using B-splines. The visualization part of the process used color-coded flow vectors over each triangular panel to depict the flow. The goal of this project is to facilitate rapid investigation of a large range of shape options during the early design stages. The system is currently undergoing tests in cases where the analytical solution is known.

Perhaps the most unusual subject presented at the conference was by Dr. A.R. Turner-Smith (coauthor, R. J. Jefferson) of the Oxford Orthopaedic Engineering Centre (UK). His talk was titled "Analysis and Presentation of Human Back Shape in Scoliosis." Scoliosis is a disease which causes a significant deformation of the shape of the spine. Early detection of the onset of the deformity is a key factor in its treatment. It is therefore necessary to be able to determine whether the deformation is increasing, and if so how rapidly. This is ordinarily done by x-rays; however, limiting the number of x-rays is highly desireable, both from a radiation and an expense point of view. Hence, the problem is to attempt to approximate the location of the spine and the amount of asymmetry from back surface shape. In the system developed at the Orthopaedic Centre, manually placed anatomical landmarks are used to define reference planes from which successive analyses (over a time span) are compared. The estimates of the location of the vertebrae using this method correlate well (about 0.8 correlation coefficient) with x-ray measurements. The efficacy of the process is highly dependent on the consistency of posture of the patient and the proper location of the landmarks. An open question, the answer of which would have significant advantages to Turner-Smith and Jefferson, is how to describe the back surface shape in such a way that the subjective landmarks now used would no longer be needed. Comparison of the current condition with that

measured much earlier, perhaps at other clinics, might then also be possible.

Conclusions

Total attendance at the meeting was about 70. It seemed the meeting was primarily publicized in the UK, so there were only about ten attendees from elsewhere in Europe, and perhaps four from the US. Nonetheless the conference brought together a wide range of experts working in the general area of surface representation and design, including some rather diverse areas of both applications and theory, which indicates the broad importance of the topic.

The conference brought some fundamental contributions in surface design and approximation being made by researchers in the UK, elsewhere in Europe, and the US. While this review points out important advancements from various countries; e.g., cyclide surfaces and radial basis function approximations from UK, stability and roundoff error analysis from the US, and the multiaffine approach to Bernstein-Bezier curves and surfaces from West Germany. In fact, the general topic is very international, with no one country dominant in any area over any extended period.

References

Beatson, R.K., and Z. Ziegler, "Monotonicity Preserving Surface Interpolation," *SIAM Journal on Numerical Analysis,* 22 (1985), 401-411.

Carlson, R.E. and F.N. Fritsch "Monotone Piecewise Bicubic Interpolation," *SIAM Journal on Numerical Analysis*, 22 (1985), 386-400.

Dyn, N. and D. Levin, "Iterative Solution of Systems Originating from Integral Equations and Surface Interpolation," *SIAM Journal on Numerical Analysis*, 20 (1983), 377-390.

Foley, T., "Scattered Data Interpolation and Approximation with Error Bounds," CAGD, 3 (1986), 163-177.

Gregory, J.A., Ed., *The Mathematics of Surfaces*, (Oxford University Press, 1986).

Handscomb, D.C., Ed., *The Mathematics of Surfaces III*, (Oxford University Press, 1989).

Hardy, R.L., "Multiquadric Equations of Topography and Other Irregular Surfaces," *Journal of Geophysical Research*, 76 (1971), 1905-1915.

Lachance, M.S., "Chebyshev Economization for Parametric Surfaces," *CAGD*, 5 (1988), 195-208.

Martin, R.R., Ed., *The Mathematics of Surfaces II*, (Oxford University Press, 1987).

Micchelli, C.A., "Interpolation of Scattered Data: Distance Matrices and Conditionally Positive Definite Functions," *Constructive Approximation*, 2 (1986), 11-22.

1/18/89

MECHANICS

2nd International Symposium on Fluid Control, Measurement, Mechanics and Flow Visualization, FLUCOME '88

by M.E. Franke. Dr. Franke is a Professor of Aerospace Engineering in the Department of Aeronautics and Astronautics at the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

The 2nd International Symposium on Fluid Control, Measurement, Mechanics, and Flow Visualization, FLUCOME '88, was held at the University of Sheffield, UK, from 5 through 9 September 1988. The conference was the second of an international conference series that was initiated by Japan in 1985 as FLUCOME '85. The conference was sponsored by the University of Sheffield and organized by Professor R.F. Boucher, as chairman, with the assistance of H.S. Stephens and Associates, Bedford, UK. The conference language was English and all papers and presentations were given in English. There were approximately 135 attendees from 14 different countries at the symposium of whom approximately 60 were from Japan, 55 from the UK, and 20 from other countries, including four from the US, five from West Germany, four from France, and one each from Czechoslovakia, China, Poland, and several other countries. As noted, almost half of the participants were from Japan.

The program included approximately 120 papers that were preprinted in a symposium proceedings, edited by Professor R.F. Boucher and published by H.S. Stephens & Associates. The symposium proceedings contains 558 pages and has a table of contents and an author index. The length of each paper was limited to five pages, maximum, unless the authors provided excess page charges. Of the accepted papers, there were approximately

24 papers withdrawn or not presented by the authors at the conference. Fourteen of these papers were submitted by authors from the Peoples Republic of China. Of these, about seven were actually submitted and published in the Proceedings; however, no authors from China actually attended the conference to present their papers. There was one attendee from China, but not one of the authors.

Program and Organization

The organization of the conference was outstanding. It was organized into 27 technical sessions with nine plenary sessions and 18 parallel sessions. No more than two parallel sessions were offered at one time. Six review papers were presented, one each on flow visualization, power fluidics, water hydraulics, laser diagnostics, computational fluid dynamics, and flow measurement.

Exhibitors (all British) at the show held in conjunction with the conference included: British Fluid Power Association, London; Bristol Industrial & Research Associates Ltd., (demonstrating transducers from TSI Incorporated, St. Paul, Minnesota); Dantec Electronics Ltd., Bristol; Flow Simulation Ltd., Sheffield (demonstrating CFD codes from Creare, Hanover, New Hampshire, and computer workstations from Sun Microsystems, Inc., Mountain View, California); Springfields Laboratory of Northern Research Laboratories, Preston; National Engineering Laboratory, Glasgow; Lucus Laboratories, Lucus Aerospace, Burnley; and the University of Sheffield (Mechanical Engineering and Chemical Processing).

Review Papers

"Advances in Water Hydraulics," a paper by J. Need Currie (Scot-Tech Ltd) which concerned advances in water hydraulics, reviewed research programs regarding new material and surface treatment developments in power transmission systems and hydraulic pumps. Of particular interest is the development of sub-sea tools and a sub-sea power pack. The tools are being developed to operate entirely on seawater with no oil interface. The paper by P. Hutchinson, of Cranfield Institute of Technology, UK, entitled "Laser Diagnostics in Fluid Flow Measurement," concentrated mainly on an extensive review of laser velocimetry. C.H. Priddin of Rolls-Royce plc, UK, gave a review paper on "Computational Fluid Dynamics for Combustion Applications." He reviewed important developments in CFD in combustion applications. He also highlighted further developments in the next few years which will significantly advance the usefulness and reduce the cost of such CFD combustion calculations.

In their paper entitled "Power Fluidic Achievements in the Nuclear Industry," E. Rimmer and L.H. Ford, of the UK Atomic Energy Authority (UKAEA), described power fluidic achievements in the nuclear industry since 1960. Many of these achievements have potential to help solve many of the problems related to repair and maintenance of contaminated equipment in the nuclear industry. Main areas of interest in their paper include ventilation control, fluid transport, flow diversion, mixing, and chemical processing. Comprehensive test programs on design procedures and application design methodology have been undertaken at UKAEA, Springfields Laboratory, the University of Cardiff, and the University of Sheffield. Power fluidics is also of interest to applications in process industries, sewage and water treatment, irrigation, etc. Details on power fluidic devices such as vortex amplifiers, all fluidic liquid pumps, circuits for double-acting pumps were given. The review by F.C. Kinghorn of the UK's National Engineering Laboratory, "Challenging Areas in Flow Measurement," was mainly concerned with challenging areas of flow measurement in industry and with technological problems. Topics included multiphase flow, direct flow measurement, pipework configuration effects, and computational fluid dynamics.

Technical Papers

While the review papers provided both current and background information, the technical papers for the most part provided new and current information. A summary of some of the technical papers and topics follows. Since the proceedings are available, I will not detail a limited number of papers, but will instead, touch very briefly on a large number of them, which I hope will stimulate the interest of readers of widely varying special interests.

A number of papers were related to fluid control systems and components. These included: a new electrohydraulic digital pressure control valve; digital simulation of dynamic behavior of poppet valves; circuits in hydraulic systems; and operating stability and compensation effects; adaptive control; servo-control systems; and computer simulation of an electrohydraulic system with transmission lines.

Numerous papers were presented on flow visualization techniques. For example, paper topics included: particle tracking velocimetry, visualization of seeded flows by means of fast movement plane light sheets, a spark-tracing method, a two-dimensional smoke tunnel, a newly developed flow quantity measuring method using laser light and an infrared imaging thermometry technique, a visualization method based on phase-moire pattern method for observing acoustic waves, and visualization using hydrogen bubbles. Flow visualization was applied to a number of applications including the

flow in the turbomachinery impeller, flow around a motor vehicle, and flow around a golf ball.

Two papers concerned tunnel ventilation, including emergency control in road tunnels. Other papers described oscillatory flow in a tapered tube, idealized oscillatory liquid flow in a pipe, hydraulic losses in nozzles, a fluidic oscillatory nozzle for efficient cleaning applications and chemical spraying applications of insecticides and herbicides, and a vortex chamber oscillating device for use in hygienic washing. Further studies of fluid devices were presented on subsonic and supersonic bistable devices and the characteristics of an ejector.

A number of papers were presented on both experiments and modeling and simulation of vortex devices, such as vortex amplifiers and vortex diodes. Vortex amplifier simulations obtained at the University of Sheffield provided significant physical interpretations not previously known and showed also that simulating the vortex flows with simple schemes produced rather good agreements with experiments. Dynamics of vortex amplifiers were studied by obtaining the small-amplitude frequency response of the amplifier.

Several papers were concerned with fluidic flowmeters of the feedback oscillator and vortex shedding types. One problem area is signal-to-noise ratio. Scaling equations for oscillatory jet devices and universal dimensionless quantities were described. New fluidic oscillators without control ports were also described, including design parameters for flowmeters. Two- and three-dimensional units were discussed.

Papers related to two-phase flow included two-phase flow measurements using an ultrasonic cross-correlation flowmeter, flow region identification phase fluctuations in gas/liquid mixture flows, measurement technique for droplet size and velocity in atomized droplet flow using a two-color, four-beam, fiber laser Doppler velocimeter.

Size and velocity measurements in a dispersed two-phase flow were made using laser Doppler velocimetry in which a fast Fourier transform method detected not only Doppler frequency for velocity but also a phase shift of Doppler signals for particle sizing. Other studies included a real-time velocity measurement system based on a digital image processing technique for analyzing two-dimensional flow fields, a recognition method to overcome the difficulty of determining the local flow direction in digital image processing techniques, a new method for the automatic measurement of unsteady flow field with vortices using a digital image processing system, and turbulence and vortex shedding using image processing. Two papers concerned the use of thermochromic liquid crystals in thermal and heat transfer studies. One of the papers gave 56 references that are applicable to liquid crystals. The other papers described the use of chemical reaction based on molecular absorption for determination and visualization of heat and mass transfer. Another paper considered the effects of heat transfer of the dynamics of pneumatic RC circuits which are needed in pneumatic control systems. Approaches to turbulent skin friction reduction were described in a flow visualization study. One approach used outer layer manipulator plates to control drag from close-packed cavity roughness. Other approaches for sparse cavities were suggested such as alteration of the sublayer structure due to an interaction with cavity vortices. The paper listed 58 references.

One paper concerned the controlled development of a turbulent-free jet that was excited by pulsing a thin, annular coaxial jet that surrounded the main jet. The surrounding jet interacted with the main jet, creating regularly spaced toroidal vortices which had a controlling action on development of the excited jet and increased entrainment.

Three-dimensional flow in an axial flow turbine cascade was studied by combined methods of hot-wire anemometry, tuft screen, and oil flow visualization. Details and understanding of the flow developed have been extended. In several papers Reynolds number effects of a number of devices were considered. One study showed that it was useful to use a modified Reynolds number in some cases.

Future Symposia and Summary

During the conference, an International Steering Committee meeting has held to plan for FLUCOME '91, a proposed 4-day symposium to be held in the US in 1991. Preliminary plans for this future conference were proposed, and preliminary details were expected to be established by December 1988.

In summary, FLUCOME '88 was well-organized, and brought together engineers and scientists in several related fields. The technical topics were varied enough to stimulate considerable cross-fertilization among the specialist attendees. It was a successful and memorable gathering. Hopefully, the proposed FLUCOME '91 conference in the US will be as successful.

12/1/88

An Investigation in Shock and Flow Processes at the Ernst Mach Institute

by Marco S. Di Capua. Dr. Di Capua is the Liaison Scientist for physics in Europe and the Middle East for the Office of Naval Research European Office. He is an experimental physicist on leave until August 1990 from the Lawrence Livermore National Laboratory (LLNL) of the University of California.

The Ernst Mach Institute (EMI) in Freiburg, West Germany, is also officially known as the Fraunhofer-Instititut für Kurzzeit Dynamik (high-speed dynamics). It is one of the 37 laboratories of West Germany's Fraunhofer Gesselschaft (FhG). Responsible for the advancement of applied science and development, FhG not only acts as a conduit for grants from the German government, but is also a contracting agency for research funded by others. At the present time there are 37 laboratories under the FhG umbrella, covering microelectronics, informatics, and automation; production and materials technology (EMI belongs to this group); process engineering; life sciences; and technical information.

The EMI was founded in 1949 by Professor Hubert Schardin as the Department of Applied Physics of the University of Freiburg. In 1959 it separated from the university and was integrated within the FhG with the name Ernst Mach Institut. Some of its activities were described by A. Roshko in ONRL-66-62 and by R.E. Reichenback in *ESNIB* 88-09:33 (1988).

EMI bears the name of Ernst Mach, the 19th century physicist, philosopher, and psychologist who had a profound influence in the development of 20th century physics. It is difficult to believe that the first pictures of the bow wave formed by a projectile in flight were obtained, following Mach's suggestions, with synchronized sparks as light sources; in 1886 – more than 100 years ago! (See Reichenbach, 1983.)

EMI conducts experimental and theoretical investigations on nonsteady shock and flow processes taking place in gaseous, liquid, and solid media. It also conducts theoretical and experimental studies, of processes associated with sudden releases of energy concentrations in explosions. Simulation of nuclear weapons effects (NWE) is also part of the EMI capability. The overlap of research area and geographical proximity between EMI and the French German Research Institute (ISL [see *ESNIB* 89-03:40-42]) in Saint Louis, France, are not coincidental – Professor Hubert Schardin is their common founder.

At the present time, EMI has two urban locations, one in Freiburg (laboratory and office facilities) and one in Weil am Rhein (offices only) that supports two proving grounds (10 km apart, 45 km south of Freiburg), one in Wintersweiler and one in Holzen. At present, EMI is organized into four main groups: fluid dynamics, terminal ballistics and impact phenomena, shock and blast, and interior ballistics and detonics.

EMI performs basic and applied research for the German Federal Ministry of Defense, which funds about 85 percent of the activities. These include both improving the effectiveness of conventional weapons, and improvement of protection against conventional, kinetic energy, and nuclear threats. Fifteen percent of their funding comes from contracts with industry and other sources.

Current research topics are:

- Propagation of shock waves in layered media that have a sound speed gradient transverse to the direction of propagation. This problem arises in a NWE context when radiation from the fireball heats air in contact with the ground. EMI performs theoretical research on this topic (Book, 1988) as well as schlieren visualizations of the shock wave originating from 0.5 gm of explosive in a chamber where gravity stratifies air and helium.
- Interactions of blast waves with targets – how can targets be protected against explosions.
- Safety aspects of munitions storage – how can storage density of ammunition stores can be increased without compromising safety.
- Issues in civil protection such as shelter specifications and stabilization of structures against shock.
- Behavior of materials under intense dynamic loadings. This includes testing the behavior of ductile materials for self-forging fragments, measurements of the spall strength of ceramics, and propagation of elastoplastic waves in solids.
- Reactor safety issues related to outside penetration of containment vessel and blast loading of concrete structures.
- Hypervelocity impact phenomena where masses range from micrometeorite to kinetic energy munitions.

Laboratories with similar missions in other countries are, among others, the Naval Surface Warfare Center (NSWC) in Dahlgren, Virginia; RARDE, Fort Halstead, and Faulness in the UK; Gramat, ISL, and CESTA (page 59, below) in France; the German Defense Forces Group WTD 52 in Bad Reichenhall, West Germany; the Ballistics Research Laboratory in Aberdeen, Maryland, and

the AC Laboratory-Spiez in Switzerland (page 61, below).

Armor-Antiarmor Research

The armor research area, whose loose description may be that of hypervelocity impact phenomena, spans the gamut from heavy armor for field applications to ultralight armors for space applications. Heavy armor against kinetic energy weapons concepts include, along with reactive armor in the form of explosive appliques, laminated materials such as ceramics, glass-metal composites, and fiber-reinforced materials. Medium-weight armor for vehicles such as the BMP, Bradley, and Marder includes laminated as well as reactive appliques. The light-armor research is concerned with laminated and woven armor concepts for protection of helicopters and humans against fragments and bullets.

Research projects in the area of ultralight "armor" include shield optimization for the Giotto satellite and calibration tests for the Long Duration Exposure Facility (LDEF). The calibration craters produced in the laboratory can be compared to craters produced by micrometeorite impact in space during orbiting of the LDEF. The crash of the Challenger has delayed retrieval of the LDEF so this project has been considerably delayed. Other space research involves simulation of micrometeorite interaction with solar panels, viewport studies for the Columbus space station, and shield studies for the Hermes European space shuttle. This aerospace work is performed in cooperation with the European Space Agency, NASA, MBB, Aeritalia, JPL, and Dassault.

The importance of this work is likely to grow, since, according to a recent *Science* article (Waldrop, 1988), an increasing amount of orbiting debris with cm sizes and velocities as high as 10 km s^{-1} can impact satellites as well as space stations.

A common thread in this research is the availability of four hypervelocity two-stage light-gas guns (G. Klingenberg, 1989; see also *ESNIB* 89-03:40-42) which have been developed to a great degree of perfection. The gun barrels are honed after every shot, a unique EMI development that provides optimum performance and maximum shot-to-shot reproducibility. Their characteristics are summarized below.

The gun for micrometeorite and space debris simulation has a caliber of 4.8 mm and can launch spheres, cubes, and cylinders with an L/D = 1 and $0.5 \leq D \leq 1.5$ mm and m 1 g up to velocities of 8 km s^{-1}. This facility is presently investigates particle impacts for space applications and the development of optical diagnostic instrumentation.

A second, larger gun has a caliber of 11 mm and launches spheres as well as cylinders with $1 \leq L/D \leq 10$. It accelerates 0.2 to 0.3 g to 9.6 km s^{-1}, while 2-3 g can reach velocities of 6.5 km s^{-1}. This facility is dedicated to the study of impact phenomena in many types of targets.

A third gun with calibers ranging from 15 to 25 mm launches spheres, cubes, and cylinders with $0.1 \leq L/D \leq 30$. A sphere of 150 g can reach 2.5 km s^{-1}, 30 g can reach 4 km s^{-1} and 5 g can reach 6.5 km s^{-1}. This facility is used for armor-antiarmor interaction studies. It is also used to investigate low-density materials as recovery media for projectiles in ballistic experiments, and to study new armors such as different steel compositions and fiber-reinforced materials. These guns are located in Freiburg.

A fourth gun, in the Wintersweiler proving ground, has a 40-mm caliber and launches spheres, cubes, cylinders with $0.1 \leq L/D \leq 30$, segmented projectiles, and real fragments. A 300-g object can be accelerated to 3 km s^{-1} and 70 g to 4.5 km s^{-1}. Extraordinarily flexible, this gun can also operate as a conventional powder gun with calibers up to 100 mm. The target room has an inside volume of 80 m^3 and is qualified to contain up to 2 kg of explosive at atmospheric pressure. Its qualifications under vacuum have not been determined yet. This facility, built at a cost of about $1 million, has been commissioned in stages since 1986.

All these facilities have a full complement of shadowgraph stations for velocity measurements, multiple exposure x-ray imagers, and high-speed imaging equipment.

At Holzen, I was introduced to a new type of flash x-ray source produced by Scanditronics AB, (75590 Uppsala, Sweden). The x-ray tube in their Scandiflash unit has a demountable anode-cathode assembly. Consequently, the tube is sturdier and cheaper to operate than sealed x-ray tube sources.

Shock and Blast Research

The Shock and Blast Research Division at the Wintersweiler proving ground investigates the interaction of shock and blast waves with structures and materials intended for protection shelters. Thus, a comparison between the response to static and dynamic loadings can be obtained. A spherical shock-pressure chamber and steady-state-pressure shock tube apply dynamic loads to building elements such as reinforced concrete slabs, brick walls, doors, windows, etc. I describe these facilities in some detail below.

The spherical shock-pressure chamber, with a diameter of about 2 m, is used for the impact loading of flat specimens with dimensions as large a 1.2 x 1.2 m with pressure pulses as high as 25 bar with rise times of about 5 ms. The test proceeds as follows. The vessel is pressurized, with equal pressures on both sides of the specimen. A diaphragm separates one side of the specimen from a vacuum chamber. The test begins when detonating cord ruptures the diaphragm, thus releasing the press-

ure on the diaphragm side of the specimen. The loading then suddenly appears on the other side of the specimen.

Concrete with glass-fiber reinforcing bars is presently under test. This reinforcement may be desirable for transparency to electromagnetic radiation. Concretes with a distributed-fiber reinforcement are also under test. The fibers are 0.05- to 1-mm-diameter, 2- to 3-cm-long copper-plated steel needles mixed into the concrete slurry. These needles provide a statistical reinforcement that is effective in all directions (Hansen, 1989). As an example, this fiber reinforcement allows displacements as large as 25 mm over spans of 1 m of a 7-cm-thick concrete plate loaded with a pressure of 6 atm. Another advantage is that the fibers provide effective shielding against electromagnetic interference (EMI) and electromagnetic pulse (EMP) (Kaspers, 1987). The second facility is a baffled shock tube that applies a sudden constant pressure to a sample. The test section of this tube, 2.4 m in diameter, accommodates entire building structural elements such as walls, doors, blast-protection windows, etc. Present tests involve dynamic loading of bulletproof glass windows.

Ballistics Research at the Holzen Proving Ground

The Holzen proving ground, which is more isolated than the Wintersweiler ground, is the rounds firing location. It is the ome of groups that perform work on explosive physics, interior ballistics, outer ballistics, and terminal ballistics.

A topic of interest of the interior ballistics group is the replacement of gunpowder by liquid propellants in cannons (Knapton, 1989; Reichenbach, 1988). This work is performed in collaboration with BRL and Dynamit Nobel. As a regenerative system this concept is attractive for a multiple shot cannon. In such a cannon, a piston separates a monopropellant (hydrazine) reservoir from the combustion chamber. This chamber consists of the gun barrel, closed at one end by the projectile and the other end by the piston. As the combustion proceeds, the piston pressurizes the propellant, which is then admitted into the combustion chamber through a set of injector orifices in the piston. The atomization, vaporization, and turbulent combustion of the propellant are extraordinarily complex and have some parallels with processes that take place in monopropellant rocket engines. Severe combustion instabilities have ruptured combustion chambers of developmental hardware, and EMI, in collaboration with Rheinmetall AG is performing measurements in the combustion chamber (Steffens, 1989) to determine which feedback process is responsible for the instability.

Research on shaped charges involves study of explosively formed projectiles (EFP) (Weimann, 1989), spherical liners, and conical liners. The principle of EFP's is the same as the principle of a shaped charge. However, tailoring of the detonation of the explosive and the shape of the liner in an EFP delivers a projectile with a small axial velocity gradient and a small L/D ratio. Up to now projectiles have been formed with lengths roughly equivalent to the caliber of the charge.

Spherical liner charges have been of interest to the oil industry to fracture oil-bearing formations. The desirable features of these charges are that they are short enough to fit along the diameter of the casing of the well and produce a forward as well as a backward jet that penetrate the rock.

Another advantage of charges with spherical liners is that a larger fraction of the liner mass, typically 50 percent, participates in the jet as opposed to 20 percent in the case of conical liner charges. This participation, of course, is at the expense of jet velocity, 5 km s^{-1} for a spherical charge as opposed to a 8 km s^{-1} for a conical charge. EMI investigates these geometries as well.

Interest on spherical liner charges also arises because their penetration is more effective at large standoffs. Therefore they are effective against reactive armors when used in tandem with a more conventional conical liner charge. Of course, the reverse jet of the spherical charge causes some practical difficulties which are now being slowly overcome.

Other EMI research involves a comparison of conical, hemispherical and EFP charges for underwater hull penetration. This is an interesting application because water, which has a small residual strength (see *ESNIB* 89-03:40-42) must be penetrated before the steel hull, where a large-diameter hole is desired. Present results indicate that a spherical charge may be the ideal for this application because of the lower jet velocities and larger liner mass participation.

With special attention to the disruption of projectiles by brittle materials smaller diameter conventional guns are used to study the target penetration processes in glass armors (Hornemann, 1989).

Conclusions

The EMI facilities are a unique national asset, utilized to capacity, and manned by a fixed number (constant over the past few years) of very capable physicists, engineers, and technicians. Contractual obligations cause a relentless push to deliver results to sponsoring agencies. Consequently, the regrets voiced by EMI personnel are quite similar to those voiced by contract R&D personnel in the US; i.e., that they would like to have more time to pursue new ideas and perform their own research.

Regrettably, I was not able to discuss armor concepts or projectile penetration in more detail. This may be due to a combination of factors: the subject of the research is sensitive; EMI is a "national facility" that performs research for third parties; FhG highly prizes contractor-client confidentiality; report distribution is limited; and,

finally, EMI itself prefers to maintain a low profile. All these factors reduce the visibility of a unique, first-class, research laboratory.

References

D. L. Book, "16th International Symposium on Shock Tubes and Waves," ONRL Report 8-008-C (1988)

Hansen, V., and D. Stein, Ruhr Universität, Bochum; D-463 (1989), see also: F. Kaspers (1989).

Hornemann, U., "Terminal Ballistic Resistance of Glass Against Shaped Charge Penetration," in *Proceedings of the 11th Int.ernational Symposium on Ballistics,* Brussels, Belgium (1989).

Kaspers, F., "Electromagnetic Properties of Steel Fiber Reinforced Concrete in the RF and Microwave Ranges", *in Proceedings of the 1989 EMC Symposium*, Zurich, (1989).

Klingenberg, G., "Light Gas Gun Experiments," *in Proc.eedings of the 11th International Sympsium on Ballistics*, " Brussels, Belgium (1989).

Knapton, J., "Electrical Ignition of HAN-Based Liquid Gun Propellants," same as: (Klingenberg, 1989).

Reichenbach, H.E., "Contributions of Ernst Mach to Fluid Mechanics" *Annual Review Fluid Mechanics* 15, 1-28, (1983).

Reichenbach, R.E., "Liaison Visit to Fraunhofer Institute für Kurzeit Dynamik," *ESNIB* 88-03:33-34 (1988).

Steffens, U., "Physical Aspects in the Dynamic Behavior of Liquid Monopropellants," same as: (Klingenberg, 1989).

Waldrop, M., "Taking Back the Night", *Science*, 241, 1288-1289, (1988)

Weimann, K., "Experimental and Numerical Investigations of parameters Influencing the Formation of Projectiles by Explosives," same as: (Klingenberg, 1989).

1/16/89

OCEANOGRAPHY

Physical Oceanography Symposium

by Dr. Thomas Kinder, Scientific Officer in the Meso/Large Scale Physical Oceanography Program for the Office of Naval Research and Dr. Alan Brandt, Program Manager for the Coastal Sciences Program of the Office of Naval Research.

Gibraltar Experiment Symposium

A "Taller sobre la Oceanografia Fisica del Estrecho de Gibraltar" (Symposium on the Physical Oceanography of the Strait of Gibraltar [the Gilbraltar Experiment]) was held in Madrid from 24 through 28 October, 1988. The meeting was jointly sponsored by the Sociedad Espanola de Estudios para la Communicacion Fiji a Traves del Estrecho de Gibraltar (SECEG), the Instituto Espanol de Oceanografia (IEO), and the Office of Naval Research. Organizers for the meeting were Jose Luis Almazan Garate (SECEG), Gregorio Parrilla (IEO), Harry Bryden (Woods Hole Oceanographic Institution), and Thomas Kinder (ONR).

The Gibraltar Experiment was an intensive field investigation of flow in the Strait of Gibraltar from October 1985 to October 1986. The primary hypothesis of the experiment was that hydraulic control exists in the strait, and that it is a key to understanding the dynamics of the flow. This idea is in marked contrast to previous ideas about strait flows (frictionally dominated). Other scientific goals of the experiment included understanding the effect of the strait on adjacent bodies of water (the Alboran Sea and the Gulf of Cadiz) and understanding how to monitor the strait over long periods.

There was general agreement among the investigators that hydraulic control (i.e., Froude number greater than one: water flow faster than the speed of internal gravity waves) does occur in the strait at some locations at some time. There was vigorous debate, however, on the quantitative details of the hydraulic conditions and on the dynamical implications of the controls. The strait is near a "maximal exchange" condition, where the transport of water is limited by the hydraulic condition, but the exchange may be submaximal more frequently than maximal.

Low-frequency flow in the strait (i.e., periods of a few days or so) is as energetic as the tides and is nearly in geostrophic balance. The low-frequency fluctuations are coherent throughout the strait, and have a period of about 10 days or so. The total outflow from the Mediterranean appears to be near previous estimates (perhaps 10^6 m^3/s but only 70 percent or so of this outflow can be considered "pure" Mediterranean water (the distinction is important for estimating mixing within the strait and for inferring Mediterranean evaporation rates).

As a consequence of the strong flows in the strait, water which is normally resident at a depth of about 700 m in the western Mediterranean flows directly out of the strait. As it flows towards the strait, it forms a narrow,

deep boundary current along the African slope. The existence of this outflow and the boundary current are attributed to a combination of Bernoulli aspiration and rotation-topography interaction, respectively.

Although the nonlinear hydraulic control is a critical dynamical effect, the friction can not be ignored completely. Direct dissipation measurements found values up to 0.001 W/kg – about six orders of magnitude above open ocean values. Estimates of bottom friction, based on Ekman models, also indicate high friction. Energetic calculations show that the friction probably does not affect the energy of the flows significantly, but that friction must be taken into account for local momentum balances.

Tidal analysis of sea-level and pressure-gage data gave details of the dominant semidiurnal tide. Curiously, the M2 element of tidal propagation in the strait is southward; whereas, in the adjacent North Atlantic it is northward. This results from the tendency of the semidiurnal tidal current to approach geostrophic balance: the across-strait phase difference is a manifestation of the required across-strait sea-level difference responding to the enegetic along-straight flow.

Meteorological measurements showed that the levantes (strong easterly wind events) are not simply Bernoulli flows, accelerating to a maximum speed at the narrowest point of the strait, and then decelerating. Instead, the interaction of the synoptic pressure field and the local orography form a small low-pressure region west of the strait, such that the along-strait wind continues to accelerate westward of the narrows.

Radar observations of surface roughness were made, using both a standard marine radar at Gibraltar and a synthetic aperture radar flown on board a B-17 aircraft. Because of the associated shallow convergences (and divergences) associated with the internal phenomena such as lee waves, bores, and solitons in the strait, time series of the sea-surface patterns reveal details about the subsurface evolution of the currents and the pycnocline.

Trace metal (Ni, Cd, and Cu) concentrations show that a significant component of the Atlantic inflow comes from the Spanish shelf northwest of the strait. The high metal concentrations appear to be derived from natural concentration processes ("nutrient trap") on the shelf.

Several engineers from the University of Madrid presented discussions of strait flows in the context of classical hydraulic theory. While not directly applicable to Gibraltar, their presentations demonstrated the effects of irregular bottom, rotation, and time variation on the well-understood solutions to steady flow in a regular domain.

Rotating tank and analytical investigations of waves generated near abrupt topography were presented by French and Moroccan scientists. Although highly idealized, these studies contribute to understanding phenomena in Gibraltar and to strait dynamics in general.

In summary, the Gibraltar Experiment returned a large quantity of high-quality data that are suitable for addressing experimental objectives. Significant results are emerging already (13 papers in refereed journals to date), and more will appear in the near future (eight are presently submitted or in press). SECEG will publish a symposium proceedings (extended abstracts) in the spring; copies may be obtained from the organizers. Several of the Gibralter scientists are planning to contribute to the NATO conference on strait dynamics which is tentatively scheduled for summer 1989 (in France).

1/18/89

PAN-EUROPEAN RESEARCH

BRITE-EURAM: The European Community Research Program on Manufacturing Technologies and Advanced Materials

by J. F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for Industrial assessment in computer science and telecommunications.

Introduction

BRITE-EURAM combines the BRITE (Basic Research in Industrial Technologies for Europe) and EURAM (European Research on Advanced Materials). The first research under the BRITE Program started in early 1986 and under EURAM in late 1987. In Novem-

ber 1988, the BRITE Evaluation Panel judged that 80 percent of the projects were progressing well. The program had helped to consolidate industrial transborder alliances and to create new ones. It had benefitted small and medium-sized companies through involvement in research and the resulting market opportunities. Smaller and less developed states had participated fully in the BRITE Program. Finally, a substantial number of important results are appearing which depended on transborder collaborative research.

The advance notice of the first call for proposals was published in July 1988 for BRITE-EURAM and the first call for proposals made in December 1988. The deadline for proposal submission was 15 March 1989, the contracts should start about December 1989.

The Technical Content of the Program

With a budget of 439.5 million ECU (about $659 million) for the period 1989-1992, the program will concentrate on the research and development most likely to meet goals critical to competitiveness of the Community's manufacturing industry.

The technology areas were selected after extended consultation. This involved inputs from a postal survey of 1000 companies, inputs from individuals and professional and trade associations, and from industrial technologies and advanced materials working groups of the Industrial Research and Development Agency Committee. These four technical areas of the new program are described in the following paragraphs.

Advanced Materials Technologies. This area will concentrate on the development, processing, and application of improved or new materials and material processing. The work will cover materials and composites based on metals, polymers, and nonmetallic materials and will cover materials for a range of specialized applications. However, developments of materials already covered by European Strategic Program of Research in Information Technology (ESPRIT) deal with magnetic, magneto-optical, and optical thin films for sensors, recording media, and heads; optical layers and specific materials for optoelectronics; ceramics and polymers for integrated circuit packaging and substrates; and superconducting thin films for low-current applications and devices. These will be excluded from the BRITE-EURAM Program in cases where there is overlap.

Metallic Materials and Metallic Matrix Composites. A particular focus of this class of materials is in those industries where improved materials can be exploited by designers to reduce operating and maintenance costs, including savings in energy, necessary for success in the market. The goals will be:

- Extended working life of components
- Higher operating temperatures for increased thermal efficiency
- Better and more effective material processing techniques.

Materials for magnetic, optical, electrical and superconducting applications. Polymer-bonded anisotropic permanent magnets or massive segments of metallic glass for applications such as electric motors, security systems, ore separation, medical equipment, and magnetic levitation for transportation vehicles are examples of use for these materials. Optical materials are important for optical communication such as laser-beam delivery systems. Among materials for electrical applications are those for electrochemical devices. High-temperature superconductivity materials may have use in components for reduced energy consumption. The goal will be improved materials and materials processing for the above.

High-temperature nonmetallic materials. The objective herewill be to:

- Design methods for products based on ceramics, glass, and amorphous material
- Improve monolithic and ceramic composites and metal/ceramic interfaces for industrial applications
- Improve processing techniques and quality control strategies.

Polymers and organic matrix components. The goals for this sector of the work are:

- Development of polymers for specific applications
- Achievement of more cost-effective process techniques for parts made from polymer and polymer matrix composites
- Design rules for the specification and manufacture of engineering polymers and composites
- Develop new polymers with improved recycling attributes
- Improve product assurance techniques.

Materials for specialized applications. This sector will deal with biomaterials – improved materials for the packaging industry, biomaterials, and more advanced materials for the building and civil engineering industry. The goal will be improved materials and their processing for these specialized applications.

Design Methodology and Assurance of Products and Processes. The development of techniques to improve product quality and the reliability and maintainability of structures and manufacturing systems by clarification of the design aims for both product and process – and by refinement of the criteria against which the attributes are measured – are objectives. The exploitation of materials for sensors, and the reduction in the whole-life costs of sensors are included in this program.

Quality, reliability, and maintainability in industry. The goals of this sector include:

- Improved performance measurement for manufacturing operations in a wide variety of industries
- Improved and more predictable physical and environmental behavior of products
- Improved quality control strategies
- Design rules for reliability and maintainability of components, structures, and systems including machinery operating under varying conditions.

Process and product assurance. The goals of this sector include:

- Reduction of whole-life costs of sensor systems for process control
- Exploitation of materials properties for application in sensors
- Use of advanced measurement techniques for more cost-effective examination of topology
- Improved energy control for industrial application
- Improved nondestructive testing methods for product assurance.

Application of Manufacturing Technologies. In this area, the task is to identify and address the needs of the manufacturing industry, particularly the less advanced sectors, many of which are mainly made up of small and medium-size companies. Modeling of physical processes will be a valuable instrument for progress. The use of flexible materials will be addressed. The work will mainly emphasize product and process development, transferring and adapting technology already used in other sectors. This should complement work in ESPRIT where information technology systems for advanced manufacturing and computer-aided manufacturing are being developed.

Advanced manufacturing practices. Here the goals are to:

- Identify means for improving manufacturing practices in specific sectors
- Transfer and adapt technology already used in other sectors.

Manufacturing processes for flexible materials. The goals in this sector are:

- Increased process flexibility
- Reduction in waste of materials
- Improved process and product quality.

Technologies for Manufacturing Processes

Surface techniques. With a better understanding of how surface systems behave, it should be possible to model systems to optimize selection. With some exceptions, such as in parts of the process industry, it is unlikely that existing knowledge is sufficiently complete to support the use of expert systems to justify their development. This is an area where collaboration is needed to bring complementary expertise together and ensure that equipment suppliers and users are able to integrate the different technologies into cost-effective applications using advanced information-handling technologies. The goals are:

- Cost-effective surface treatments for industrial applications
- Techniques for quality assurance and control of the treatment process.

Shaping, assembly and joining. The goals of this project are:

- Improved methods for shaping process and assembly
- Improved joining techniques to improve reliability and reduce defects
- Methods for testing and bonding welded joints to improve reliability of results and service predictability
- Design method for joining
- Better understanding of beam/workpiece interactions for industrial power-beam processes.

Chemical processes. Here the goals are to:

- Improve predictability and yield in chemical processes
- Obtain membrane materials with improved characteristics
- Improve performance of membrane processes
- Obtain new systems for separation in hostile environments.

Particle and powder processes. The goals for this project are:

- Improve techniques for particle production to optimize product shape, structure, and stability
- Obtain cost-effective techniques for particle categorization and process performance
- Obtain better approaches to handling and separation
- Obtain cost-effective methods for small lots of high-quality powder.

BRITE-EURAM Implementation in a Global R&D Context

Industry has confirmed the requirement for a better awareness of emerging technological development as an important element of the technology strategy of industrial companies, large and small. For reinforcing the market pull of the BRITE-EURAM program this awareness is needed. The European Commission will take further initiatives, including workshops, in consultation with other agencies. The aim is to bring together the global science and technology trends with the planning needs of individual companies, realizing that this cannot be limited to a single sector but must also involve related sectors in which are major customers and existing or potential suppliers of materials, equipment, and expertise.

The program will be open to enterprises from all sectors of industry and research organizations, including universities within the Community and the European Free Trade Association (EFTA) countries. Projects involving partners from EFTA countries will be welcomed where their participation can contribute to the competitiveness of the manufacturing industry as a whole. The projects must fulfill the normal eligibility criteria with the EFTA partner being additional to the requirement that there be at least two legally independent industrial enterprises from at least two different member states of the EC. There will be no financial contribution from the Community toward the participation costs of partners from EFTA countries who will be required to contribute to the program overhead.

Within the program there will be four separate forms of support. The industrial applied research will be the principal action with over 90 percent of the budget. There will also be focused fundamental research with up to 7 percent of the budget.

Feasibility awards for small and medium enterprises will get about 0.5 percent of the budget, and coordinated activities will receive about 1.5 percent.

Past experience in BRITE and EURAM indicates the following breakdown for expenditure by category:

	Percent
Advanced Materials Applications	30
Design and Assurance of Products	21
Manufacturing Systems	21
Technologies for Manufacturing Processes	21
Administration	2.5
Personnel	14.5
	100.0

Comments

BRITE-EURAM Technological Days were held in Brussels at the Palais des Congres from 31 January through 2 February 1989. At that time a report was given on the results achieved thus far with BRITE and EURAM separately. This was followed by a discussion of plans for the joint program BRITE-EURAM in the 5-year period, 1989-1992.

Since I attended this meeting my more complete report on the program will soon appear.

12/12/88

PHYSICAL ELECTRONICS

The 19th International Conference on the Physics of Semiconductors and the 4th International Conference on Superlattices, Microstructures, and Microdevices

by Roland E. Allen. Professor Allen is a Principal Investigator in the Physics Department at Texas A&M University, College Station, Texas.

The International Conference on the Physics of Semiconductors (ICPS), held every 2 years, is the principal meeting on basic semiconductor research. At this year's conference, held from 15 through 19 August 1988, the presentations covered the usual wide range of topics, from nascent devices to new fundamental discoveries. An attempt to include high T_c superconductivity appears to have been a failure; there were only four poster presentations in this area, and the plenary talk by the Soviet theorist V.L. Ginzburg was cancelled. This may have been for the best, since the scope of the conference and the number of participants was already large. There were about 420 papers accepted (same as the 1986 meeting in Stockholm, and more than the 1984 meeting in San Francisco); out of 760 abstracts submitted, 175 were presented as talks (4 plenary, 27 invited, and 144 contributed) and the remaining 245 as posters.

Although the conference was held in Warsaw, the great majority of the contributions were from Western countries as well as Japan and China, with a modest number from the Soviet Union and very few from Eastern European countries (if the collaborations involving Western laboratories are excluded). Virtually all the significant research reported came from the US, Western Europe, and Japan, although there was a moderately interesting plenary talk Monday morning by V.B. Timofeev (Institute of Solid State Physics, Academy of Sciences of the Soviet

Union) on photoluminescence studies of the integral and fractional quantum Hall effects.

The conference took place in the Palace of Culture and Science, a "gift" from the Soviet Union that is spacious and attractive on the inside and rather ugly on the outside. Since the talks were presented in four parallel sessions, the topics discussed below are necessarily biased by my own research interests.

The Fourth International Conference on Superlattices, Microstructures, and Microdevices (also called the 5th Trieste Semiconductor Symposium) was a satellite meeting held the week before ICPS-19, at the International Center for Theoretical Physics (ICTP) in Trieste, Italy. In his welcoming remarks, the Director of ICTP, Abdus Salam, a Physics Nobel Laureate mentioned his campaign to get "developing" nations to spend a larger fraction of their gross national product on basic research. For the sake of simplicity in the following text, I will discuss presentations of particular interest from both conferences without distinguishing between venues.

Surfaces

D.J. Chadi of Xerox Palo Alto opened ICPS-19 with a plenary talk, "Structural and Electronic Properties of Semiconductor Surfaces." During the past 11 years, a variety of experimental techniques, with some theoretical support, have provided definitive characterizations of both the atomic and electronic structures for a number of semiconductor surfaces.

Perhaps the most interesting story involves the Si(111) 7x7 surface. Many models were proposed for its structure, but the principal lasting contributions were:

1. Lander, 1963 – vacancies and adatoms, 2x2-like cells
2. McRae, 1983 – dimers and stacking faults
3. Binnig and Rohrer, 1983 – scanning tunneling microscopy (for which they won the Physics Nobel Prize)
4. Takayanagi et al., 1985 – definitive structure.

A number of STM studies confirm the main features of the Takayanagi et al. model, which involves vacancies, dimers, adatoms, and stacking faults within the complicated 7x7 surface unit cell.

The structures of III-V (110) surfaces are essentially the same as the structure determined for GaAs(110) in 1978; the anion rotates outward and the cation inward. For Si(100) (2x1), there is apparently a coexistence of symmetric and asymmetric dimers. The Pandey "π bonded" model for Si(111) (2x1) and the Tong "vacancy-reconstructed" model for cation-terminated III-V (111) (2x2) surfaces seem to be well-confirmed. Si(111) + As appears to give an "ideal" 1x1 surface.

Other surfaces are not so clear-cut. A model for As-terminated GaAs(111) is weakly supported by angle-resolved photoemission measurements, which are consistent with the theoretical $E(\vec{k})$. The structure of GaAs (100) is stoichimetry-dependent; a stable annealed structure is 4x6. The differences between Ge and Si surfaces are not well-understood; i.e., there are still many unsolved problems involving some of the simplest semiconductor surfaces.

Observations by scanning-tunneling-microscopy (STM) of Si and GaAs surfaces, and of adsorbates on these surfaces, were discussed by R. Feenstra of IBM Yorktown Heights. It is always fascinating to see the rich structure in the STM images, indicating that surfaces and adsorbates are very complicated at the atomic level. The unoccupied and occupied states associated respectively with Ga and As at the GaAs (110) surface can be separately imaged in scanning tunneling spectroscopy, providing beautiful agreement between the observations and simple theoretical ideas. An isolated oxygen atom appears to chemisorb at a particular Ga-As bridge site. There is a connection with Fermi-level pinning. An isolated O atom becomes negatively charged, with a shift in the local Fermi level. Near the edges of Sb islands, there are additional states within the band gap, and Feenstra conjectured that these states might produce Fermi-level pinning. Au and Bi on GaAs(110) were also studied.

There were two interesting talks on surface states: C. Janowitz et al. (University of Kiel, West Germany) reported photoemission and inverse photoemission studies showing that the occupied surface state bands for InSb(110) and GaSb(110) protrude above the valence band edge, into the band gap. These are the only III-V semiconductors where this is known to happen, and it presumably is caused by the strong spin-orbit interaction for the heavy anion Sb. (The occupied surface states, like the valence band itself, are associated primarily with the anion.) In the same session, M.S. Hybertsen (Bell Labs, Murray Hill, New Jersey) and S.G. Louie (University of California, Berkeley) reported first-principles calculations of Si 111):As and Ge (111):As surface states, with many-body effects included in Hedin's "GW" approximation. In an earlier talk, Louie and his coworkers at Berkeley had described an alternative approach to many-body effects in solids, supposedly valid for even strongly-correlated systems (variational quantum Monte Carlo). This inclusion of many-body effects is a new direction in solid-state electronic structure calculations. It will be important in semiconductor physics because previous first-principles calculations,in the local-density approximation, yielded band gaps that were about 40 percent too small.

Band Offsets and Schottky Barriers

As reported at both the ICPS and superlattice conferences, there are two general approaches to a theoretical understanding of heterojunction band offsets. The first is to perform first-principles calculations in the local-

density approximation. This is the road taken by C.G. Van der Waale (IBM Yorktown Heights) and R.P. Martin (University of Illinois), and by D.M. Bylander and L. Kleinman (University of Texas), in work mentioned but not presented at these conferences. This approach presumably gives good results for the valence band offset ΔE_v, but it is computationally expensive. A. Baldereschi and coworkers (from Trieste [affiliation not given]), in work that was presented in talks at both conferences, also take a first-principles approach, but use first-order perturbation theory, with a virtual crystal such as $Ga_{1/2}Al_{1/2}As$ taken to be the unperturbed system. In this "linear response" approximation, the offset is independent of the growth direction and the abruptness of the interface. The results are claimed to be in good agreement with more rigorous first-principles calculations.

The other general approach is to assume some simplistic model that determines the band offset in terms of characteristic energies for each semiconductor. The most popular schemes involve aligning two reference energies, which might be called E_0^A and E_0^B for semiconductors A and B. In the closely related Schottky barrier problem for semiconductor/metal interfaces, one aligns the reference energy E_0 of the semiconductor with the Fermi energy E_F of the metal.

This general idea was invented in 1977 by C. Tejedor, F. Flores, and E. Louis, who called E_0 the "charge neurality level." A related idea, dating back to a 1965 paper of V. Heine, is "metal-induced gap states" (MIGS) or "virtual gap states" (ViGS). In this latter picture, the semiconductor band gap is regarded as containing "virtual states," associated with complex wave vectors k. The virtual gap states below E_0 supposedly want to be filled, and those above E_0 to be empty, so E_0 in a semiconductor is postulated to play the same role as E_F in a metal.

There are two controversial points: (1) Are band offsets and Schottky barriers determined by any reference energy E_0? For example, there is a large body of work, including some presented at ICPS and discussed below, that indicates many Schottky barriers are due to defects. (2) If there is such an E_0, how is it to be interpreted physically? As mentioned below, one can have a charge neutrality level without MIGS or ViGS.

In regard to the first point, there was a poster presentation by W.E. Spicer and coworkers of Stanford University, indicating how Schottky barriers for GaAs and other III-V's can be explained by an "Advanced Unified Defect Model" that involves antisite defect levels. In another poster, R. Ludeke et al. proposed a model for Schottky barriers that is based on defect or impurity levels. And L.J. Brillson and coworkers (Xerox, Webster, New York) had a talk, given by R.E. Viturro, showing low-energy cathodoluminescence and soft x-ray photoemission evidence for discrete states at metal/GaAs interfaces, when the GaAs is melt-grown. These interface states have a high enough density to account for the observed Schottky barriers. One should also recall the STM talk by Feenstra, mentioned above, showing that adsorbates as well as native defects can produce Fermi-level pinning and Schottky barrier formation.

There is thus strong evidence for a defect mechanism of Schottky barrier formation. This does not, however, preclude an intrinsic mechanism that will dominate the defect mechanism when the concentration of defects is small. If so, experiment indicates that the original model of Schottky and Mott, in which the barrier height varies linearly with the metal work function, is usually not adequate, and that the idea of a reference energy E_0 is closer to the truth. Then what is E_0?

Several different interpretations were mentioned or presented. The first is the ViGS (or MIGS) picture, described above; in one version E_0 is the energy $E(k_0)$ associated with a branch point k_0 in the complex plane. Another interpretation involves a rather ad hoc correlation with transition-metal impurity levels. A third, first presented by Sankey et al. (1986), involves dangling-bond levels. It is interesting that all of these interpretations make nearly the same quantitative predictions for Schottky barrier heights and band offsets, because each reference level is an "effective mid-gap energy" and there are consequently only small differences in the calculated positions. A talk by M. Lannoo and coworkers (Institute Supérieur d'Electronique du Nord) showed that transition-metal impurity levels "are effectively pinned to the average dangling-bond energy level," and this explains why the transition-metal levels correlate with band offsets.

Three groups have recently emphasized the role of dangling bonds: Lannoo and Allan, and their coworkers; Tejedor and Flores and their coworkers; and Stepien, Jedrzejek, and Allen. The first two groups were represented at this meeting. In work not directly discussed at the meeting, all three groups have found that most intrinsic Schottky barriers and band offsets can be explained by dangling-bond resonances. Even if the *resonance* is very much broadened by bonding across the interface, it is still found, in model calculations, to be effective in pinning the Fermi energy. According to this interpretation, therefore, the reference level E_0 is simply an average dangling-bond energy.

Other Topics

Defects. The nature of some of the best studied bulk defects is still uncertain. As G.A. Baraff of Bell Labs pointed out, regarding the prominent EL2 defect in GaAs, "so many experiments on EL2 have now been performed and interpreted that they now conflict with each other. As a result, no microscopic model can satisfy them all and any theoretical calculation of a specific model of

EL2 must be in conflict with at least some of the experimental interpretations." S.T. Pantelides of IBM (Yorktown Heights) discussed his proposal that what has always been interpreted in amorphous Si as a 3-fold coordinated atom, with a dangling bond, is really a 5-fold coordinated atom, with a "floating bond." In another talk, his colleagues at IBM, P.C. Kelires and J. Tersoff, reported a calculation that gives a lower energy for 5-fold coordination, in support of this idea. The model interatomic potential that was used is not well tested, however. Pantelides also reported that the theoretical energies associated with three difference diffusion mechanisms – vacancy, interstitial, and Pandey's concerted exchange – are all -4 eV.

Computer Simulations. Only two groups appear to be currently active in realistic computer simulations for semiconductors. The Trieste group (R. Car, M. Parrinello, and coworkers) had two talks. The first was given Monday by W. Andreoni, on Si, Ge, and GaAs microclusters. This work was largely motivated by the experimental work of R.E. Smalley and coworkers at Rice University. Up to 80 atoms were used, with an emphasis on structure rather than dynamics. The second talk was given Friday by F. Buda, on high-temperature diffusion in Si. Qualitative agreement was found with the experimental diffusion coefficient as a function of temperature. However, the very short times available in these molecular dynamics simulations (~1 picosecond), elicited some questions about the interpretation and validity of the results. These simulations are still at a rather primitive stage.

In another talk, I presented the simulations of M. Menon and myself for molecules and clusters reacting with GaAs and InP(110). Al shows a tendency toward cluster formation, and O_2 dissociates in the initial stages of oxide formation.

Low-Dimensional Systems. At both ICPS and the superlattice conference, there was considerable interest in fundamental studies involving quantum wires. For example, at the superlattice conference there were two consecutive talks, both from Bell Communication Research, on the quenching of the Hall effect in GaAs quantum wires as B→O, one by F. Peeters and the other by M.L. Roukes et al. At ICPS, there were two consecutive and rather beautiful invited talks on "Medoscopic Systems," by B.L. Altshuler of Leningrad and A.B. Fowler of IBM (Yorktown Heights). Fowler discussed the observations of both quantum confinement and quantum transport, in quantum dots (~3000 Å across) and quantum lines (~2000 Å across). There were two sessions with a total of eight talks Monday afternoon, on "2D→1D" and "Low-Dimensional Systems." For example, J.P. Kotthaus of the Institut für Angewandte Physik, Universität Hamburg, gave a nice presentation; submicron lithographic techniques make it possible to create laterally periodic field effect devices with widths of ~100 nm.

At the superlattice conference, many studies were reported of optical and transport properties, phonons, excitons, etc. in superlattices, and of the aspects relevant to potential devices – resonant tunneling, strained-layer superlattices, amorphous superlattices, etc. At ICPS, the best talk on devices was the plenary talk by A.Y. Cho, "MBE and Its Applications." He claimed that quantum well detectors are now better than HgCdTe. In response to remarks from the audience, Cho granted that metal-organic chemical vapor deposition (MOCVD) and liquid phase epitaxy (LPE) sometimes have advantages over molecular beam epitaxy (MBE).

Finally, there was a rather exciting session on the fractional quantum Hall effect and the recent discovery by A.C. Gossard, H.L. Stormer, D.C. Tsui, and their coworkers of an even-denominator fractional quantum Hall effect. They have apparently resolved the nature of this new state through tilted-field experiments, and find agreement with a theory of F.D.M. Haldane and E.H. Rezayi.

Proceedings

The Proceedings of ICPS-19 should appear in about 6 months and will cost $132. Contact Dr. Jacek Kossut, Institute of Physics, Polish Academy of Sciences, Al. Lotnikow 32/46, 02-668 Warsaw, Poland. The Proceedings of the superlattice conference will appear in forthcoming issues of *Superlattices and Microstructures*. Contact Professor John D. Dow, Department of Physics, University of Notre Dame, North Bend, Indiana 46556.

Reference

Scubrey, O. F., R.E. Allen, and J.D. Dow, *Surface Science* 168 (1986), 367.

11/26/88

Developments in Solid-State Power Electronics at Switzerland's ASEA Brown Boveri

by Marco S. Di Capua. Dr. Di Capua is the Liaison Scientist for physics in Europe and the Middle East for the Office of Naval Research European Office. He is an experimental physicist on leave until August 1990 from the Lawrence Livermore National Laboratory of the University of California.

The ASEA Brown Boveri Corporation (ABB) in Baden, Switzerland, is the world's largest electrical equipment manufacturer. ABB resulted from the merger, in early 1988, between the Swedish electrical concern, ASEA, and the Swiss electrical concern, Brown Boveri Corporation (BBC), whose activities have been the subjects of previous ONR London reports (*ESN* 1965, *ESN* 1973). This merger concluded a difficult period of declining sales for BBC due to the rising strength of the Swiss franc.

BBC first succumbed to pressures to restructure in an attempt to strengthen the company's earning capacity. As often happens, one of the first steps was the curtailment of research laboratory budgets. Restructuring, however, did not turn the tide, and ASEA, who had a substantial surplus of cash, came to the rescue as a merger partner. While it is too early to tell how well the integrated company will function, it was apparent from my visit to ABB that the staff of the research laboratories has been decimated and morale is now quite low.

One bright spot that I wish to report on concerns improvements in semiconductor devices for pulse power switching applications. A second bright spot is the application of semiconductor diodes as quench protectors for superconducting magnets. I was able to discuss these developments with Dr. Janis Vitins of ABB, CH-5401 Baden, in a recent liaison visit to Switzerland.

Semiconductors for Pulse Power Switching

Modern electronics rely on the ability to control currents in semiconductor devices that use silicon as the basic material. Microelectronics emphasizes a decrease in device size and an increase in the density of elements as well as the operating speed of circuits. Power electronics, instead, emphasizes an increase in the current- and voltage-handling capability of semiconductors while improving operating speeds. Semiconductors can now handle higher currents and higher voltages faster than ever before.

Application of silicon-controlled rectifiers, also known as thyristors, in motor drives, power supplies for automated processing machinery, speed controls in electric locomotion (land and marine) and ac-dc-ac conversion for high-voltage dc transmission of electrical energy provides the forcing function for power electronics development at ABB.

The switching of tens of kV voltages in fractions of a microsecond, up to very recently, has been the domain of electron tubes such as hydrogen thyratrons and triodes. As in other areas of electronics, technological advances in power semiconductors allow the replacement of vacuum tubes with solid-state devices for this application as well.

The advantages of replacing electron tubes with solid-state devices are numerous, among them a higher efficiency, minimal firing jitter and constant characteristics over an unlimited number of pulses.

The fundamental advances that allow single switching elements to hold off 3 kV, and conduct 2000-A, 0.4-μs pulses at a repetition rates as high as 5 kHz arise from parallel progress on:

- Device modeling
- Materials processing
- Device packaging.

This article reviews advances accomplished at ABB like:

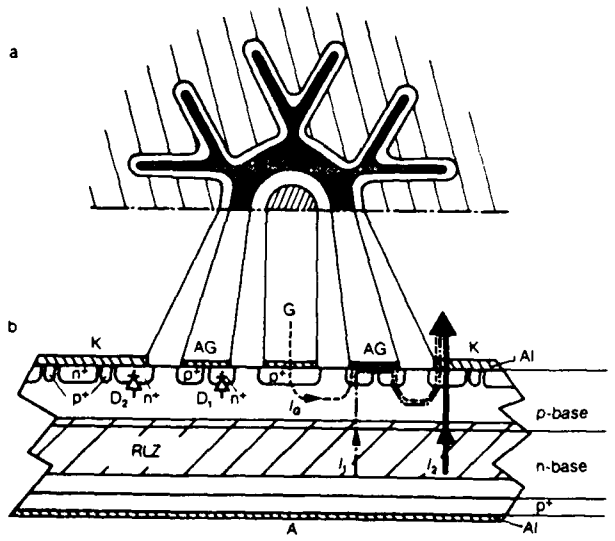
- Improved electrical flashover strength at the edge of the silicon wafer to a point where it matches the intrinsic breakdown strength of the silicon
- Minimization of the turn-on time with an acceptable ratio of gate energy to total conducted pulse energy
- Minimization of the forward voltage drop while maximizing the blocking voltage
- Prevention of thermal runaway in the wafer by effective heat dissipation
- Symbiosis of magnetic and thyristor switching that accomplishes repetitive high-speed switching.

Flashover strength at the edge of the wafer. Perhaps one of the largest difficulties facing the implementation of any switch for pulse power applications is to match the intrinsic breakdown strength of the switching medium to the breakdown strength at the edges of the medium where it interfaces with the envelope. In a conventional switch, the medium is a gas or vacuum that becomes a plasma (see page 14, this issue) and the "envelope" is a plastic, glass, or ceramic container. The switching medium in a power thyristor is silicon with an intrinsic breakdown

strength of 5 MV m^{-1}. The envelope surrounding the silicon is either gas or vacuum.

Optimization of the shape that maximizes the breakdown strength of the periphery (Leisten, 1987) followed a modeling and experimentation process that incorporates the bevel geometry and the effect of the PNP doping of the silicon wafer. Beveling and doping the edge of the wafer, however, is not sufficient. The thyristor assembly incorporates an elastomer gasket in intimate contact with the beveled edge of the silicon. Present ABB devices utilize the intrinsic strength of the silicon fully, allowing blocking voltages (which are roughly proportional to the thickness of the silicon) as high as 5 kV for a 1-mm-thick wafer.

Fast turnon of power semiconductors. A fast turnon leading to a low conducting-state voltage drop, with acceptable triggering energy requirements, is essential in pulse power switching. Pulse power applications require a 40-fold or greater leap in current risetimes, from 5.0E + 08 A s^{-1} in traction applications to 2.0E + 10 A s^{-1} or greater. To accomplish these current rise rates, ABB thyristors incorporate a built-in amplifying gate. This gate



a Cathode side of the silicon wafer
b Cross-section showing the layer structure

G = Gate
AG = Amplifying gate
K = Cathode
A = Anode
Al = Aluminium metallization
RLZ = Space charge region
I_a, I_1, I_2 = Paths of the currents participating in turn-on

Figure 1. Principle of the turn-on behavior of an asymmetrical fast switching thrystor

is spread in a fingerlike fashion, over the surface of the wafer as shown in Figure 1 (Schweizer, 1987).

When the triggering pulse is applied to the gate G (Figure 1) the triggering current flows to the cathode K along a path comprised of a p + region at the G, the base, a series connection of n + and p + regions at the amplifying gate AG and finally an n + region at K. The flow of gate current from the p base into the n + region of AG produces electron release from the n + region of AG into the space charge region. Circuit current I1 then flows from the anode A, through AG into K, now producing electron release from the n + region of K into the space charge region. At this moment, the cathode turns on and these electrons constitute the main circuit current I2.

This description suggests that reliable fast turnor requires I1 to be sufficiently high and of sufficient duration to release electrons uniformly from the periphery of the cathode proximal to the "fingers." If the pulse is too short or not intense enough, electron production at the cathode is insufficient and the resistive losses in the switch become unacceptable. Yet, I1 must be limited to avoid excessive energy deposition at the amplifying gate. A minimum of 100 A with a pulse duration greater than 300 ns are required for an adequate cathode turn-on.

For pulses shorter than a few hundreds of microseconds, the turnon may be adequate even though only a small fraction of the cathode area beyond the edge may participate in the current conduction.

Magnetic switching plays a fundamental role in the shaping the I1 current pulse. RC networks, connected in parallel with the thyristor provide the initial current surge, and saturable magnetic cores in series with the discharge circuit complete the shaping of this amplifying pulse. Infrared recombination radiation arising at the amplifying gate is an effective diagnostic to optimize I1.

Optimization of carrier lifetimes. Carrier lifetimes establish the lower limit to attainable periods in repetitive operation. Long carrier lifetimes, however, are desirable from an energy dissipation viewpoint because they result in lower conducting state voltage drops (Vitins, 1988). Since the conducting state voltage drop in a fully turned-on thyristor increases almost as the square of the hold-off voltage for a constant current density and carrier lifetime, it is desirable to operate a device with the largest carrier lifetimes that are compatible with the desired repetition rate. Special silicon processing, in conjunction with the optimal design of the edges of the wafer described above, yields thyristors with large hold-off voltages, acceptable voltage drops capable of large repetition rates.

Temperature control of the wafer. The rise in forward-conducting voltage with increasing temperature of the silicon has challenged ABB device designers to control the temperature profiles in the wafer. The input heat flow, due to resistive dissipation in the wafer is highly two-dimensional. It spreads towards the interior from the edge of the amplifying gate fingers proximal to the cathode. The ABB design provides an effective heat flow path by precisely assembling the wafer and the anvils that clamp it. Uniform contact pressure between the anvils and the wafer prevents the formation of hot spots in the silicon.

Quench Protection Diodes for Superconducting Magnets

Superconducting magnet windings require a current bypass in case the winding quenches and is no longer superconducting. Otherwise energy stored in the remaining magnets will dissipate in the quenched winding.

A proposed "active" current bypass system has diodes at room temperature, in conjunction with heaters embedded in the magnets. In this approach the leads provide a heat conduction path from ambient temperature that constitutes a serious thermal penalty.

A passive quench protection system consisting of silicon power diodes connected to the winding terminals inside the cryostat provides an alternate approach. This presents some difficulties in high-energy particle accelerator magnet applications, because of radiation damage in the semiconductor. This damage increases the forward diode voltage, leading to enhanced energy deposition.

Improvements in radiation damage resistance are obtained at the expense of decreased reverse breakdown voltage. Exposure of ABB diodes to fluxes as high as 1.0E + 13 neutrons cm^{-2} has shown only a 6-percent forward voltage increase for a 200-V reverse breakdown voltage device (Carcagno, 1988).

On the basis of this data, ABB semiconductor diodes (DS 6000) will be incorporated as quench protectors in the magnets of the HERA storage ring at the German Electron Synchrotron Laboratory (DESY) in Hamburg. Practical experience with these diodes will demonstrate whether they are sufficiently reliable for quench protection applications in larger systems such as the superconducting supercollider (SSC).

Conclusions

A combination of semiconductor modeling, circuit modeling, and heat conduction modeling in conjunction with challenging electrical and optical measurements and sophisticated manufacturing techniques has resulted in thyristors that seriously challenge electron tubes for pulse power switching applications.

One exciting development for repetitive pulse applications is the combination of semiconductor and magnetic switching technology. This combination could simplify complex pulse power systems such as ETA II (Prono, 1988) or linear induction accelerators (Wampler, 1988). In these systems, a large number of switching components have to operate reliably at large repetition rates (Prono, 1988).

Semiconductor switches are already replacing electron tubes in some pulse power applications. Some of the system advantages thus have been confirmed. It is expected that in a short time, in pulse power systems where the benefits of reduced jitter, high repetition frequency, operating reliability, and ruggedness are crucial, will incorporate power semiconductors.

Another exciting possibility results from the extension of the "smart power" chip concept (Paxman, 1988) to the pulse power field. In this concept, the controlling chip incorporates the control circuit. Semiconductor modeling using three-dimensional Poisson solver codes allows physicists to design wafer configurations that support maximum voltages with a minimum depth of semiconductor. Innovations in tailored semiconductor doping allow chips to increase voltage holdoff in the lateral dimension by shaping the electric fields. Therefore, it is now possible to build chips where the low-voltage IC control circuit can be isolated from the high-current, high-voltage unit.

If this "smart power" chip technology were to be extended into the pulse power domain, one could conceive of a one-chip repetitive switch, handling a few kiloamperes at a few kilovolts, with 5-kHz repetitive rates, controlled by a couple of volts driving a 50-ohm impedance.

Up to now, pulse power switching has taken advantage of components developed originally for industrial applications. At the present time, companies like ABB are willing to undertake device development when the potential of a substantial market (many thousands of units) exists downstream or when another party underwrites the R&D costs. It is likely that pulse power in the future will rely on the application of adequate, but nonoptimal, off-the-shelf industrial components, unless a large commercial or military market develops for thyristors designed specifically for pulse power applications. Similarly, without significant investment, the concept of a pulse power generator on a chip (except for energy storage components) will remain a gleam in the eye of the Liaison Scientist.

The use of passive semiconductor diodes for quench protection of superconducting magnets appears to be a new exciting application. The DESY tests will show whether diodes will become a permanent protection fixture in superconducting magnet installations.

References

Carcagno, R., "Quench Protection Diodes R&D", *The Lattice (SSC Newsletter*, (1988), 5-7.

ESN 19-10: 179-182 (1965).

ESN 27-6: 152-153 (1973).

Leisten, O. et al., "New Manufacturing Methods Lead to a Breakthrough in Thyristor Technology," *ABB Corporation Report HEKSV PB 8719* (1987)

Paxman, D. "Smart Power," *Physics World*, 2 (1989) 26-28.

Prono, D. et al.,"Engineering Aspects and Initial Performance of ETA-II," in *Proceedings of the 7th International Conference on High-Power Particle Beams*, Paper CC4, (1988), 214-219.

Schweizer, A. et al.,"Fast Switching Thyristors Replace Thyratrons in High Current Pulse Applications," *Brown Boveri Review*, (1987), 7; also in *Proceedings of the 6th. IEEE Pulsed Power Conference*, (1987), 591-4.

Vitins, J. et al.,"High Power Semiconductors for Pulsed Switching." in *Proceedings of the 1st European Symposium on Electromagnetic Launcher Technology*, Delft, (1988).

Wampler, S., "Lab Technology for Linear Induction Accelerators May Soon Be Used Commercially" *LLNL Newsline*, Vol. 13, No. 40 (1988), 1.

2/10/89

Spontaneous and Stimulated Emission by Ballistic Electrons in Semiconductor Heterostructures - Theoretical Investigations at Israel's Technion

by Marco S. Di Capua.

During my recent visit to the Technion (Haifa, Israel), Professor Amiram Ron told me of some very exciting developments concerning the behavior of ballistic electrons (Heiblum, 1989) in heterostructures.

High-purity semiconductor alloys such as GaAs/GaAlAs, grown as single crystals by molecular beam epitaxy, allow fabrication of 100-nm regions in which electrons have mean free paths of comparable dimensions. Electron motion in these regions is collisionless, allowing electrons to behave as if they were traveling in a drift tube (hence the ballistic description).

In a heterostructure consisting of alternating layers of different semiconductor alloys the conduction band edge varies periodically in space. Electrons that traverse the structure feel a periodic potential along their direction of motion. Consequently they emit electromagnetic radiation in a transverse direction as they are periodically accelerated by the potential.

Theoretical research by Ron and his students has:

- Determined the rate of spontaneous emission from electrons injected in such a structure
- Quantified the number of photons emitted (in a direction perpendicular to the electron direction of motion)
- Analyzed the populations of electrons and photons
- Examined the possibility of using such a heterostructure as an oscillator and a traveling wave amplifier.

Detailed results appear in two recent publications (Bottom, 1989 and 1989a).

Spontaneous Emission Calculations

Ron and his collaborator determine the rates of spontaneous emission by:

- Solving the Schröedinger equation for the ballistic electrons in the periodic structure
- Obtaining the energy states and the wave functions for the electrons (the so-called "mini-bands" of the superlattice)
- Calculating the transition rates from the excited states to lower energy states in the dipole approximation.

Ron performs the calculation specifying the periodic potential and solving the Schroedinger equation with this periodic potential. Satisfying the boundary conditions provides a dispersion relation for the κ vector of the electron wave function in the mini-bands of the superlattice. This calculation yields the energy eigenstates of the system and the wave functions associated with these eigenstates.

Ron then specifies the matrix elements between the excited states and the lower energy states of the electrons with a Hamiltonian consisting of the product between the linear momentum of the electron and the magnetic vector potential. The dipole approximation (radiation wavelength $>>$ electron wavelength) allows the κ vector of the electron before and after the transition to be nearly equal.

The total rate of spontaneous emission calculated by Ron, is lower than the hydrogenic rate by the square of the ratio of the Bohr radius to the period of the structure and by the ratio of the frequency to the frequency associated with the 13.6 eV H ionization potential. It is increased however by the square of the ratio of effective masses (15 approximately) and square root of the dielectric constant.

Parameters typical of GaAs devices – i.e., electron velocities of 5.0E+05 m s^{-1}, potentials of 0.1 eV, dimensions of 5x20 μm^2, and current densities of 100 A cm^{-2} – yield, according to Ron, rates of infrared photon emission of 5.0E+08 s^{-1}.

These calculations are a preliminary step to establish whether conditions in such a device would allow stimu-

lated emission taking advantage of the "inverted" energy population of the electrons injected in such a structure.

Traveling Wave Amplifier and Oscillator Calculations

To determine whether the system will behave as a travelling wave amplifier Ron and his coworker, calculate the rate equations for the electron population coupled with an applied electromagnetic field power flux density, while neglecting the spontaneous emission. Their results show that positive gain can be achieved. This gain is likely to become stronger as the injected electrons have a narrower distribution in energy.

To obtain the current density required to reach the oscillation threshold, Ron sets the rate of growth of photon equal to the losses. Under these conditions, a current density of 1.0E+04 A cm^{-2} allows the typical GaAs heterostructure device to reach self-oscillation.

According to Ron, a laser based upon ballistic electrons in heterostructures bears a strong resemblance to free electron lasers (FEL's [see following article]) where the periodic characteristics of the structure and the electron velocity determine the radiation wavelength. In a heterostructure laser, variations in the gap energy of the superlattice provide the periodic potential as the electrons undergo collisionless motion in the structure. The difference is, however, that in the case of a free electron laser, radiation is emitted in the direction of motion, while in a heterostructure device the radiation takes place in the transverse direction. Moreover, given the low energy of the electrons and the distances that characterize the periodicity of heterostructures, quantum mechanical effects come into play and the bands of the periodic structure determine the transitions that are allowed. From this viewpoint, such a laser has a more restricted tunability.

Summary and Conclusions

The work described in this article demonstrates how imaginative application of fundamental physics, coupled with judicious approximations, leads to the prediction of familiar phenomena (FEL-like oscillation) in new configurations (heterostructures). Experimental verification will tell whether the predictions will prove true. At this point, the ball is in the court of the device designers!

References

Bottom, M., and A. Ron, "Spontaneous Emission by Ballistic Electrons in Semiconducting Heterostructures," submitted to *Solid State Communications*, (1989).

_____, "Stimulated Emission by Ballistic Electrons in Semiconducting Superlattices," *Applied Physics Letters*, (1989a) 418.

Heiblum, M., et al., *Ballistic Electron Transport in Hot Electron Transistors*, IBM Thomas Watson Research Center, Yorktown Heights, N.Y. (1989).

2/13/89

PHYSICS

The 10th International Free Electron Laser (FEL) Conference

by V.L. Granatstein and A.W. Fliflet. Dr. Granatstein is with the University of Maryland, College Park, Maryland, and Dr. Fliflet is with the Naval Research Laboratory, Washington, D.C.

The 10th FEL meeting, an important international conference, held this year in Jerusalem, Israel, from 29 August through 2 September 1988, had 114 registered participants representing 11 countries. Fifty of the participants were from the US, 22 from Israel, and the balance mostly from Western Europe. Poland, Japan, and China were also represented. A total of 103 papers were presented, of which 45 were posters given in two poster sessions. The papers included status reports on the major FEL projects in the US and Western Europe and surveys of FEL research in Japan and in China. US dominance in this field at the conference, at least as observed by us, was clear both in number of attendees and quality of papers. This is reflected in our selection of papers in the text which follows.

Review of the Presentations

One highlight was the scientific progress reported by the Los Alamos National Laboratory (LANL) with a high-power, RF linac-driven FEL including generation of ~400 MW of peak power at $\lambda = 10.6$ μm with over 4 percent efficiency. Fractional linewidth was less that 0.2 percent – near the limit determined by the pulse length of the

electron beam – and sidebands were found to be readily suppressed by detuning. Experimental results on the use of a Littow grating in the cavity to successfully suppress sidebands were also reported.

Initial performance of the 10.6-μm, 45-MeV induction-linac-driven FEL at the Lawrence Livermore National Laboratory (LLNL) was also reported. T. Meyer of the US Strategic Defense Initiative Organization (SDIO) described the ground-based FEL planned for construction at White Sands, New Mexico, and reported that a decision between deploying an RF linac or induction linac system would be made in the coming year.

L. E. Elias at the University of California at Santa Barbara (UCSB) reported on the early operation of a user facility employing a submillimeter wavelength FEL driven by an electrostatic accelerator; experimental studies in material science, biology, and medicine are underway. Reports were presented on plans for similar user facilities at the FOM-Institute for Plasma Physics in the Netherlands, at the Weizmann Institute in Israel, at the University of Central Florida, and at the National Institute of Standards and Technology. Opportunities for FEL applications in medical research were described by C. Houston of the SDIO and A. Louis of the Hebrew University of Jerusalem. A. Lumpkin of LANL described applications of FEL's to research on high-temperature superconductors.

Another application of FEL's which was discussed concerned electron heating in magnetic fusion plasmas; this application requires megawatts of average power at a wavelength of about 1 mm. The leading candidate for this application to date is the CW gyrotron; FEL's are of interest since they scale well to submillimeter wavelengths, are tunable, and may be capable of very high average power per source. R. Jong of LLNL reported on progress in developing a repetitively pulsed (5 kHz), induction-linac-driven FEL for this application. The LLNL approach involves the production of gigawatt-level peak powers using a multikiloampere, 10-MeV electron beam. V. Granatstein of the University of Maryland presented a very different FEL design, involving a short-period wiggler (microwiggler), and a sheet electron beam, which would allow for driving the FEL with an inexpensive, conventional, dc power supply. Microwiggler development work was also presented by speakers from the Massachussetts Institute of Technology (MIT) and the University of Tel Aviv. By reducing the beam energy (Doppler upshift) needed to operate at given wavelength, such wigglers could significantly reduce the cost and shielding requirements of the electron accelerator. Several groups reported plans to investigate the use of electromagnetic wigglers to increase the FEL operating frequency. Experiments on gyrotron-powered electromagnetic wigglers were reported by MIT's R. Temkin.

The conference included several papers on a FEL-like cyclotron resonance maser configuration called the Cyclotron Auto-Resonance Maser (CARM). The CARM is of interest as a multimegawatt source of millimeter- and submillimeter-wavelength radiation based on a 0.5- to 1.5-MeV beam. Planned experimental studies of the CARM, which is also a candidate for the plasma heating application, were described by G. Bekefi of MIT and A. Fliflet of the US Naval Research Laboratory (NRL). The MIT experiments include 35-GHz and 140-GHz CARM amplifiers. The 35-GHz experiment is driven by a 100-kW magnetron and based on a 1.5-MeV, 5- to 300-A beam obtained by emittance filtering of a 20-kA beam from a field emission diode. The 140-GHz experiment will use thermionic cathode technology at voltages up to 700 kV. A 100-GHz CARM oscillator experiment based on a 600-kV, 200-A, 70-nanosecond electron beam is in preparation at NRL and a 250-GHz oscillator experiment based on a 500-kV thermionic cathode electron gun is also planned.

A paper on applications of FEL's operating at UV wavelengths (below 300 nm) was presented by B. Newman of LANL. Most of these applications, which include investigation of atomic and molecular spectroscopy, surface physics, and biological structures, will require very low levels of FEL amplitude and phase noise. M.E. Couprie of the Laboratoire pour l'Utilization des Rayonnement Electromagnetique (LURE) Université de Paris-Sud (Orsay, France), who had just returned from the USSR Novosibirsk), reported on an FEL driven by the VEPP-3 storage ring which had achieved lasing over the wavelength range 100-1500 A; this Soviet result using an optical-klystron configuration is believed to be the shortest wavelength operation of an FEL to date. Other optical klystron experiments, planned or in progress, were described by LURE and by the Brookhaven National Laboratory scientists. Ongoing harmonic FEL studies to achieve coherent, vacuum UV radiation were described by B. Bamford from Stanford University. Planned studies of harmonic FEL operation at millimeter wavelengths were described by NRL's H. Freund.

An interesting scientific controversy arose concerning the degree of coherence in the UCSB submillimeter FEL. It had been previously reported that with a 5-second electron pulse, this FEL had operated with a single longitudinal mode having a fractional linewidth in the range 10^{-7}-10^{-8}. However, at the Jerusalem conference, B. Levush of the University of Maryland reported results of a simulation of the UCSB experiment which indicated that after 5 seconds, many (~ 100) strong competing longitudinal modes would still exist. This issue was a focus in a roundtable discussion on FEL coherence; the evidence that UCSB had presented for single-mode operation (viz., almost constant radiation amplitude over the

full 5-ms pulse duration) was disputed as constituting definitive evidence of single-mode operation.

L. Shengang of the University of Electronic Science and Technology of China in Chengdu reported on two experimental FEL projects. One was a 35-GHz, pulseline-accelerator-driven FEL amplifier with a helical wiggler and an axial magnetic guide field. The beam voltage is 700 kV and the current is 500 A. An "extended interaction oscillator" provides the input signal via a quasi-optical input coupler. A peak power of 1.5 MW with 47-dB gain at 2-percent efficiency was reported. Multifrequency output including superradiant emission at 37.5 GHz was observed. The other project is a Compton FEL driven by a 22-MeV RF linac upgraded for FEL research with a peak current of 0.5 A and a 1-μsecond macropulse. Operation at 10 μm is expected by 1990.

J.M. Buzzi of the Laboratoire de Physique des Milieux Ionises, Ecole Polytechnique (Palaiseau, France) also reported on a very carefully designed millimeter-wave FEL driven by an electron beam from a pulseline accelerator. Continuous tunability from 75 GHz to 270 GHz was demonstrated at an output level of about 10 MW. At 120 GHz, 20-percent efficiency was achieved, which is unusually high for an FEL with an untapered wiggler magnet.

The development of a 6-MeV, 10-kA induction linac for FEL research was reported by K. Mima of the Institute for Laser Engineering in Osaka, Japan. Beam energy variation is designed to be <3 percent during the 70-nanosecond pulse. Initial FEL experiments at reduced voltage and currents have produced 1 MW at a wavelength of ~1 mm. Planned experiments include a 498-μm amplifier driven by a CH_2F laser and development of a UV source using a CO_2-laser-driven electromagnetic wiggler.

Summary

The Jerusalem conference revealed FEL's as a maturing technology with unique capabilities over a huge wavelength span from UV to mm waves. Generally, power, efficiency, and tunability are superior to other coherent radiation sources, but questions concerning the degree of coherence which is achievable remain to be answered. FEL applications are at hand in medical and materials research. Potential applications in the future range from deployment in ballistic missile defense systems to deployment in controlled thermonuclear reactors.

12/13/88

Spectroscopy and Collisions of Few Electron Ions

by David J. Land. Dr. Land is a research physicist in the Nuclear Branch of the Research and Technology Department at the Naval Surface Warfare Center, Silver Spring, Maryland.

A conference, devoted to and designated as the Spectroscopy and Collisions of Few Electron Ions (SCOEFI '88), was held from 29 August through 2 September 1988 at the Central Institute of Physics in Bucharest, Romania. The members of the Institute's small but enthusiastic Atomic Collisions Physics Group were anxious to host such a conference, which had been eagerly anticipated for 2 or 3 years. The realization of this goal was enhanced by the occurrence of a second, well-established conference, Trends in Quantum Electronics '88 (TQE '88), which provided the mechanism for several required facilities. SCOEFI '88 was originally scheduled to be held in mid-July, and the change in date to allow it to coincide with TQE '88 resulted in the loss of a few invited speakers, mainly from the US, because of conflict with the academic schedule. Nevertheless, this conference attracted a broad selection of atomic scientists with ten invited speakers coming from Western Europe, eight from Eastern Europe, one from Asia, and seven from the US. There were approximately 40 participants in all. By contrast, TQE '88 attracted about 400 scientists.

As the conference designation indicates, focus was placed in the dual areas of spectroscopy and collisions in atomic physics. Within the area of spectroscopy, topics could be categorized as dealing with the properties of structures, including new measurements of the Lamb shift for heavy atoms and high-resolution measurements of the hyperfine structure splitting, or as dealing with the response of structures to a probing field, including the interaction of atoms with strong electromagnetic fields. Within the area of collisions, topics included both theoretical and experimental investigations of inner- and outer-shell atomic ionization and excitation and of ion-solid collisions.

Selected Subjects

Following are brief summaries of a few of the talks which on the basis of my personal background and interests appeared to be the most significant contributions.

Crystallization of particle beams. Experiments planned for the production and detection of crystallized particle beams at the Heidelberg test storage ring were discussed by D. Habs (Max-Planck Institut für Kernphysik, Heidelberg, West Germany). A crystallized beam is one in which the ions are frozen in position relative to the other ions of the beam. Such a beam is generated through either electron or laser cooling and reflects strong correlation within the beam. Experiments have been performed in which a collection of 100 to 1000 ions have been stored in a Penning trap and cooled to a very low temperature (T = 1-10 mK). The analysis of the behavior of such a small number of ions confined in this trap shows that the particles are restrained to concentric spheroidal shells but can wander freely over the shells. Theoretical studies using molecular dynamics to apply this experimental situation to a storage ring predict stability for certain helical configurations. The problem is to see if crystals observed in the trap can be seen in a storage ring and to determine to what extent a storage ring behaves like a gigantic trap.

Positron emission in heavy-ion collisions. In collisions between two heavy ions with atomic numbers Z_1 and Z_2, back-to-back, narrow e^+-e^- peaks are observed superimposed over the usual continuum spectra, provided $Z = Z_1 + Z_2$ is sufficiently large. These peaks are usually interpreted in terms of the strong Coulomb forces that exist when the two nuclei are close to each other, although this model usually requires that Z be larger than a critical value, which is about 170. In a presentation by L. Gr. Ixaru (Institute for Physics and Nuclear Engineering, Bucharest, Romania) an alternative description is suggested in which there exists a much longer range interaction between the nuclei causing the occurrence of electron resonances. According to this model, as the nuclei approach each other the vacuum is heated such that an electron can be excited from the Dirac sea to the positive-energy continuum, thus creating an e^+-e^- pair. This creation can take place at subcritical or supercritical values of Z, in concurrence with experimental results. While the issue is not settled, this approach constitutes what the author called a fresh look at the problem.

Electron correlation processes in ion-atom collisions. An area of particular interest today in atomic collision physics involves processes in which two or more electrons interact during the collision to produce experimentally observable effects. N. Stolterfoht (Hahn-Meitner-Institut, Berlin, West Germany) gave a succinct summary of this subject in which emphasis was placed on distinguishing, firstly, correlated effects occurring because of the static (e.g., Hartree-Fock) wave function of the initial or final state versus effects taking place from electron-electron interaction during the course of the collision arising because of the scattering wave function and, secondly, electron screening from electron correlation. The separation of these effects is not straightforward. Theoretically, effects of electron correlation may be thought of in terms of the difference between a real physical problem and the corresponding description of this problem when studied within the independent particle model in which electron-electron interactions are replaced by the interaction of each individual electron with an average atomic field. Specific experimental problems which exhibit these effects include double ionization, double capture, and transfer excitation.

Correlated systems in atomic collisions. A program which has been ongoing at Texas A&M University, College Station, for more than a decade has as its principal goal the determination of accurate solutions to the Schrodinger equation in problems of ion-atom collisions. A summary of this effort was given by L. Ford (Texas A&M University). Recently, particular effort has been given to the inclusion of electron-electron correlation effects with a focus on the problem of double ionization induced by protons and antiprotons for which data has recently become available. The general approach in this program is to solve the coupled-channel, time-dependent Schrodinger equation. To include correlation, an initial-state correlated wave function is allowed to propagate forward in time as an uncorrelated system with a correction made at suitable time intervals to include correlation. Good agreement with experimental data for the ratio of double to single ionization total cross section for protons and antiprotons incident on helium has been achieved. It has been shown that the electron-electron correlation as well as the inclusion of non-dipole terms is necessary to obtain the observed difference in the proton- and antiproton-induced cross sections.

Doubly excited states of atoms. Three-body problems continue to challenge theoretical physics for more precise interpretation of experimental data. In this presentation, given by J. Briggs (University of Freiburg, Freiburg, West Germany), an analogy is drawn between the treatment of certain nuclear configurations, such as the positive ion of molecular hydrogen, H_2^+, and the atomic configuration of the neutral helium atom in order to use ideas from the nuclear problem to study doubly excited states of the atomic. This study is another example in which electron-electron correlation is involved. In the atomic problem one normally takes the coordinates of each electron relative to the nucleus as basic. An alternative point of view, suggested by the nuclear problem, is to define a coordinate system in which one coordinate consists of the vector joining the two electrons (in He) and a second coordinate connects the nucleus with cen-

ter of mass of the first. This leads to the introduction of hyperspherical coordinates. In terms of these newly defined coordinates, potential wells for atoms can be deduced more readily – from which the existence and number of bound states can be inferred.

Few-electron ion processes relevant for plasma edge studies. A presentation by F. Aumayr (Institut für Allgemeine Physik, TU Vienna, Austria) dealt with processes that occur at the edge of a plasma adjacent to the first wall. These processes include electron capture from H_2 and He by low-Z ions, the excitation of He^{2++} in collision with Li, and electron emission from metals surfaces induced by highly-charged low-Z ions. In particular, good agreement of theoretical calculations (Fritch and Lin) with experimental measurements for the He-Li system was found. The motivation for these studies was based both on the importance of these processes on the behavior of the plasma itself as well as on their usefulness as a diagnostic tool in determining the plasma parameters.

Concluding Remarks

The general theme of this conference focused on problems involving few-electron systems as the relative simplicity of such systems make them more amenable to detailed experimental and theoretical study. Within this domain the selection of topics was broad in scope. The field of atomic collisions has matured to the point where interest has expanded from studies in which the basic projectile-electron is the dominant interaction to processes in which secondary electron-electron interactions play a significant role in experiment. The individual presentations outlined above reflect this point of view. In addition, there were several presentations dealing with multiple ionization and with double electron capture. There were also discussions concerning the interaction of atoms in strong electromagnetic fields. The international participation of scientists noted above along with the wide selection of topics appearing in this conference should portray SCOEFI '88 as a very successful event in the eyes of the sponsor and lend strong support for future conferences in Bucharest hosted by the Institute's atomic collisions physics group.

Plans to publish the proceedings of this conference are afoot, but the publisher was not known at the time of the conference.

11/23/88

Two-Dimensional Physics at the International Conference on The Application of High Magnetic Fields in Semiconductor Physics

by Dr. John E. Furneaux. Dr. Furneaux is with the Electronics Technology Division, Naval Research Laboratory, Washington, D.C.

Approximately one-half of the papers presented at the meeting on The Application of High Magnetic Fields in Semiconductor Physics, a satellite conference to the *XIX International Conference on the Physics of Semiconductors* (Wurtzberg, West Germany, 22-26 August 1988) dealt with the physics of the two-dimensional electron gas (2DEG). In particular, there were four areas of interest and controversy which were aired at the meeting.

One area of particular interest was optical spectroscopy of multi-quantum-well (MQW) systems. D. Heiman et al., from MIT's Francis Bitter National Magnet Laboratory (FBNML), reported absorption and photo-luminescence data on heavily modulation-doped GaAs/AlGaAs MQW's taken at very low temperatures ($T < 100$ mK) and high magnetic fields. These samples were of sufficient quality that the fractional quantum Hall effect (FQHE) could be observed in transport. Heiman et al. found a spectral blue shift which appears to be due to the many-body corrections to the electron density of states in the FQHE regime. Theoretical calculations of the anticipated many-body corrections to optical data in lightly doped MQW's were presented by L.J. Sham, University of California, San Diego, and T. Ando, the University of Tokyo. Each adopted different approximations in their calculations which yielded different magnetic field dependencies for the spectra. Although some uncertainty in the data interpretation remains, it appeared that Ando's calculation, which used dynamic

screening, agreed with the experimental results presented by J.C. Maan, from the Max Plank Institute, Grenoble.

A second area was the effect of an added parallel magnetic field on the FQHE. An oral presentation was added to the program at the last minute. This was a joint presentation by P.A. Maksym, from Philips Research Labs, UK, who discussed theory, and Clark [initials unknown], from the Clarendon Laboratory, Oxford, UK, who discussed experiments. Maksym's theory included the effects of spin in a finite electron calculation of the FQHE and came up with some interesting results, but they do not seem to be consistent with the experimental data. Clark's presentation was on a controversial determination of the quasi-particle charge in the FQHE regime. The ideas were interesting but the data did not seem to support the conclusions. R.J. Nicholas from the Clarendon Laboratory, Oxford, UK, also presented some parallel magnetic field data which indicates that spin changes are important in the FQHE. J.E. Furneaux from NRL had extensive data supporting this view. Eisenstein, from AT&T Bell Laboratories, Murray Hill, also reported the destruction of the 5/2 even FQHE state by an added parallel magnetic field. The extreme sensitivity of this even FQHE state to the added parallel field was attributed to a spin-paired ground state. It is clear from all this work that spin, which has been largely neglected in the FQHE calculations, is very important and that further calculations are necessary.

A particularly controversial area concerned the possible observation of Wigner crystallization in the 2DEG realized in a GaAs-AlGaAs heterojunction. This phenomenon occurs when a low density of free electrons collectively organizes into a crystalline array due to the dominance of interelectron Coulomb energy over the electron kinetic energy. Because magnetic fields suppress the kinetic energy, high magnetic fields enhance the possibility of observing Wigner crystalization. Although this phenomenon has been observed for electrons bound to the surface of liquid He, it has not been observed in a semiconductor. Again, the presentation was added to the program quite late and was split between two points of view: R.L. Willett (FBNML), who presented transport results, and G. Deville from Saclay, France, who presented RF absorption measurements. Both experiments show interesting results at very low temperatures and high magnetic fields. The FBNML group pointed out that their data was consistent with either magnetic freeze-out due to localization or Wigner crystallization. The Saclay group claims to have seen the shear wave mode associated with the Wigner crystal due to the temperature and magnetic field dependencies of their observed resonance absorptions in the RF. However, the density dependence of the observed absorptions is more compatible with surface acoustic wave absorption as reported by A. Wixforth (University of Hamburg, West Germany). M. Shayegan (Princeton University) pointed out that his observation of the 1/7 FQHE state made the Wigner crystal phase diagram questionable. The observation of RF absorption at lower magnetic fields near 1/3 FQHE state also makes the reported phase diagram questionable. It is still unclear whether the Wigner crystal exists in a semiconductor system even in 2D.

Finally, three talks were presented on spin resonance in a 2DEG were presented. Both U. Rössler (University of Regensburg, West Germany) and E.I. Rashba (USSR Academy of Sciences) gave theoretical presentations, and Dobers (Max Planck Institute in Stuttgart, West Germany) gave an experimental presentation. Rashba presented an intuitive and physical picture of the effect of a heterojunction on the spin resonance properties of the 2DEG. Rössler presented a very accurate and complete calculation of the spin resonance properties of the 2DEG in a GaAs-AlGaAs heterojunction which fits the data of M. Dobers without adjustable parameters. Dobers presented a very complete set of experiments on spin resonance observed by microwave photoconductivity. He was able to observe not only spin resonance signals but also dynamic alignment of the nuclear spins and nuclear relaxation in these experiments. These presentations correlated very nicely with optical determinations of the 2DEG spin energy reported by Heiman and transport determinations of a number of 2DEG energy gaps including the spin gap reported by Nicholas.

11/26/88

Solid-State Physics Conference of the Institute of Physics

by Dean L. Mitchell. Dr. Mitchell is the Liaison Scientist for Solid State Physics in Europe and the Middle East for the Office of Naval Research European Office.

The annual Solid-State Physics meeting of the UK's Institute of Physics (IOP) was held at the University of Nottingham from 22 through 26 December 1988. This meeting is the IOP equivalent of the March meeting of the American Physical Society (APS). It provides the major national forum in the UK for research in solid-state and condensed matter physics as well as related research in electronic materials and applications. Also, in accord with the March APS meetings, it does not have a fixed venue. Future meetings will be held at Warwick in 1989, Birmingham in 1991, and Guilford (Surrey) in 1992. The 1990 slot will be filled by the European Physical Society, which will hold its annual condensed matter physics meeting at Exeter.

The style and format of the solid-state meeting differed considerably from its American counterpart. The morning and afternoon sessions were opened with plenary sessions comprising a total of eight talks during the 3-day meeting. After a short recess, the meetings reconvened in four parallel sessions which covered the following topics, organized as symposia:

- Irradiation, Implantation, and Processing-Induced Defects in Semiconductors
- Quantum Coherence in Metals and Semiconductors
- Ultrasonic and Phonon Propagation in Semiconductors
- Semiconductor Physics
- Implanted Muon Studies in Condensed-Matter Science
- Magnetism Toward the Nineties
- Photon Probes in the Study of Surfaces
- High Temperature Superconductivity
- Growth and Properties of Various forms of Carbon
- Computational Physics
- General Topics.

The oral presentation for the symposia were mostly invited. A few of the contributed talks were included for oral presentation; the remainder were included in the poster sessions that accompanied each symposium. The sizes of the symposia varied considerably: Quantum Coherence in Metals and Semiconductors had two sessions with five invited talks, four regular talks, and two posters while Semiconductor Physics had four sessions with four invited talks, 16 regular talks, and 110 posters. Typical of the average was the High Temperature Superconductivity symposium, which had four sessions with eight invited talks, three regular talks, and 30 posters.

The symposia topics are normally selected a year in advance in order to give the chairmen time to organize the sessions and select the invited speakers. This gives balance to the meetings by providing coverage of topics, such as muon spin resonance, that may have a small number of active research practitioners but where the physics could or should be of interest to a much wider community.

Seventy-six percent of the 600 plus participants came from universities in the UK, 15 percent from industrial or government labs in the UK, and 10 percent from abroad. The authorship of the papers reflects the same distribution. Multiauthor, multiinstitutional, and even multinational papers were very much in evidence. This trend towards multiparticipants tends to reflect the increased sophistication of solid-state research, where devices and unique measurement facilities; e.g., for synchrotron radiation, do not exist or cannot be reasonably developed in the same laboratory or even the same country. Multiparticipation is also in line with research policies of the national funding agencies such as the Science and Engineering Research Council (SERC) in the UK and international funding organizations such as the Council of Ministers for the European Community. The trend in Europe, as in the US, is to encourage multidisciplinary collaborative research in those topics chosen to have priority. Priority topics tend to reflect current popular views of what the next major new technology will be. Thrust research projects with joint university/industry participation are considered particulary attractive. These policies, which exert pressure to shift research directions to meet short-term goals, combined with the static research budgets have created some stress in the physics community. In the words of Professor R.A. (Tony) Stradling, the outgoing chairman of the Solid State Divisional Committee of the IOP:

> "The fact that the Institute has chosen to reorganize itself into Divisions, which has led to the renaming of the old Solid-State Subcommittee, serves to emphasize the changes (and in many cases the stresses) that the community is currently experiencing. Restructuring is the keynote of the times even if on occasion it seems to be being undertaken for its own sake! Research funding is being reorganized across the board with the rapid emergence of new Department of Trade and Industry (DTI), European Economic Community (EEC), and other schemes and with the prospect of a new initiative in optoelectronics. Interdisciplinary Research Centers are being created, three within the first

year in subjects of interest to this Conference. The SERC has set up a Materials Commission which will handle many of the research grant applications, which seems to have produced a proliferation of committees and which will eventually lead to many of the papers at future conferences in the series.

The theme of change was further amplified by Sir Sam Edwards, who spoke on the future of physics departments in British universities as seen from a national perspective (Dickson, 1988a and 1988b). Sir Sam chairs the governmental commission that recently surveyed the future needs in the UK for physics graduates. They also provided recommendations on how the universities should be structured to meet these needs. The most controversial aspect of the report deals with the role of research in smaller departments. The tone of the report, if not the words, suggests triage of weaker departments to allow the limited natural resources to be focused on research in the strongest departments, however they might be defined. Sir Neville Mott, in his extemporaneous comments, gently chided Sir Sam on taking a too simplistic view of physics research and education. He cited a visit to a small department in a New England university during the 1950's: although teaching was the mainstay, he was impressed by a younger and more active member of the faculty who was very enthusiastic about his research and was in the midst of preparing a proposal to ONR. Mott's message was, I believe, that we should be a little hesitant about enacting plans for the future of specific departments or institutions at a national level – particularly when the plans are developed in order to address political priorities.

Summaries of the Talks

The following summaries of symposia and plenary talks give highlights of this conference from my viewpoint. I will not review the poster sessions: however, the abstracts are included in the meeting directory and copies of abstracts in selected areas can be provided on request.

Electron transport in structures of restricted dimension or dimensionality was a major theme that pervaded several of the plenary lectures and provided a common thread in at least two of the symposia: Semiconductor Physics and Quantum Coherence in Metals and Semiconductors.

The first speaker, Dr. H. Sakaki, of the Electrical Engineering Department of Tokyo University, reviewed his research on surface superlattices, quantum wires, and quantum boxes in terms of the requirements on material and fabrication parameters. The thrust of Professor Sakaki's research interest is to explore the device potential of modified electronic band structures in semiconductors with constrained dimensions, in the range of 10-100 nm, and with the dimensionality reduced by artificial structures to produce quasi-two-dimensional (2-D), quasi-one-dimensional (1-D) or quasi-zero-dimensional (0-D) behavior. Two-dimensional FET devices have been fabricated with submicron silicon planar technology and 1-D devices with FET GaAlAs structures. The FET structure allows "dimensional tuning" of the electronic conductor channels by the use of properly shaped electrodes and adjustable gate voltages.

Professor L. Eaves, of the Physics Department at Nottingham University, was the recipient of the Mott Lecture award. He reviewed research on transport in double-barrier resonant tunneling devices which exhibit quantum mechanical interference effects at temperatures as high as room temperature. Advances in expitaxial growth of AlGaAs alloys now make it possible to grow very high quality heterostructures with variable width GaAlAs barriers separated by 1-10 nm of n-type GaAs. With symmetric barriers he observes interference fringes in the I-V transport analogous to two-slit optical interference – i.e., the result expected quantum mechanically for simple 1-D Kronig-Penny models. In transverse magnetic fields, with orbital plane perpendicular to the barriers, low field oscillations are observed which are interpreted as tunneling into "skipping" orbits: at higher field, Landau oscillations are observed. By introducing asymmetric widths for the tunneling barriers, bistable devices have been fabricated which operate at room temperature. The instability results from the difference in the trapped charge and consequently on the barrier height when polarities are reversed. As Sir Neville Mott commented at the conclusion of the talk, "How nice it is to see real experiments which replicate the figures in elementary quantum mechanics texts."

Professor M. Pepper of the University of Cambridge continued the focus on constrained electron system with his plenary talk on electrostatic confinement and 1-D transport in semiconductor structures. Pepper and coworkers independently discovered the quantized conductance (see also page 45, above) in 1-D ballistic transport which was first reported in *Physical Review Letters* 60, 848 (1988) by F.J. Van Wees and his collaborators at Delft University and Philips (Eindhoven). The effect resembles the Quantum Hall Effect (QHE) in that the resistance is quantized in units of $2e^2/h$ or e^2/h with the spin degeneracy lifted by an external magnetic field. The resistance values of the plateau, however, appear to be somewhat sample dependent and thus do not share the exquisite precision of the QHE. The experiments by Pepper and colleagues were carried out on Schottky gate FET's which reduced the dimensionability of the electron gas from three to two dimensions. Transverse n+ electrodes acted as source and drain with a buried p+ split gate mounted between source and drain to "pinch off" the electron flow to a 1-D channel. The mean-free-path for

electrons in the completed device was on the order of 10 microns, much larger than any of the other length parameters for the system.

B.J. van Wees and his collaborators at the Philips Research Laboratories at Eindhoven carried out their experiments on 1-D ballistic transport in a 2-D electron gas constricted by depletion regions underneath two narrow-spaced side electrodes. Their samples were fabricated with 200 nm of epitaxial GaAs topped by a 40 nm layer of n+ GaAlAs. The Fermi wavelength of the electron gas was 40 nm so that 1-D crossover occurred for constrictions of the same magnitude. In high magnetic fields an anomalous quantum Hall effect was observed. The plateau, in this instance, did not correspond with the number of occupied Landau levels in the 2-D electron gas, but rather depended on the geometry and relative positions of the current and voltage point contacts. This appears to be due to the transverse electron focusing effect previously observed in degenerate 3-D metals.

To date, the experiments on 1-D ballistic transport in 2-D electron systems are explainable in terms of relatively simple one-electron theories. The effects themselves can be quite novel, such as the nonadditivity of two 1-D resistances in series and the geometry dependence of the transverse resistance (Hall effect). Also, the quantization of the conductance in units of $2e^2/h$ (e^2/h with spin degeneracy removed) appears to be somewhat sample dependent and therefore may not approach the precision of the quantum Hall effect. However, the exploration of ballistic transport in lower dimensional device structures and configurations does offer a rich new ground for phenomenology as well as providing a physical basis for understanding the operation of nano-scale devices.

References

D. Dickson, "More Restructuring Urged for British Universities," *Science,* Volume 242, (1988a) 1241.

____, "Basic Science's Skies, Brightenin Britain," *Science,* Volume 242, (1988b), 664.

2/23/89

Pulsed-Power Plasma Research at Israel's Weizmann Institute

by Marco S. Di Capua. Dr. Di Capua is the Liaison Scientist for physics in Europe and the Middle East for the Office of Naval Research European Office. He is an experimental physicist on leave until August 1990 from the Lawrence Livermore National Laboratory of the University of California.

A vigorous research program on plasmas in pulsed-power systems is under way in the Plasma Physics Group of the Nuclear Physics Department at the Weizmann Institute in Rehovoth, Israel. Professor Yitzhak Maron and members of his group have been investigating the physical processes that take place in the anode plasmas of ion diodes to develop new diagnostic tools and plasma models that can be applied to plasmas in other pulsed power devices. Ion diodes are the source of positive ions in the pulsed-power particle beam inertial confinement fusion schemes that are under investigation at larger laboratories such as: Kernforschungszentrum Karlsruhe (KfK), (West Germany), Sandia National Laboratories Albuquerque (SNLA), and at the Institute for Laser Engineering (ILE), (Osaka, Japan).

The emphasis of ion diode research at the larger laboratories is oriented to the production of high-power ion beams and their focusing to high-power densities. Therefore, the fundamental understanding of anode plasmas in the diode, contributed by the Weizmann group, has been greatly welcomed by the particle beam fusion community.

To obtain the understanding, the group applies a very effective combination of careful spectroscopic measurements and numerical modeling to determine the processes that take place in the anode plasma. Among their accomplishments are:

- Measurements of velocity distributions of ions and neutrals
- Determination of electron temperatures
- Determination of absolute fluxes of ions from the dielectric substrate
- Time-resolved measurement of magnetic fields in the plasma
- Formulation of a theory that accounts for anomalous conductivity of the plasma
- Application of a laser-induced fluorescence technique to measure particle density distributions
- Studies of the role of neutrals in the expansion of the anode plasma
- Studies of the ionization instability and magnetic insulation breakdown in ion diodes.

Measurements of absolute line intensities and detailed line profiles, an exhaustive analysis of experimental data and fundamental understanding of plasma spectroscopy, have allowed this youthful group to formulate successful models for the physical processes that take place in the anode plasmas. These models explain phenomena that have been observed in larger accelerators and confirm, with experimental data, hypotheses of previous researchers.

In the future, this group will study plasma sheets in imploding plasmas as well as plasma erosion opening switches (PEOS) with a particular emphasis on how the magnetic field diffuses in the plasma. Penetration of currents, that accompanies the diffusion of magnetic field in the plasma, plays a very important role in both devices.

During a recent visit to the Weizmann Institute, I was able to discuss the ion diode plasma research program in great detail. The results of my conversations with students of Professor Maron are summarized below.

Laboratory Facilities

The group uses a medium-voltage (270 kV), 90-ns, 1-ohm pulsed-power source to drive a magnetically insulated ion diode. In a magnetically insulated ion diode, a magnetic field perpendicular to the applied electric field prevents electrons emitted from the cathode from reaching the anode, while the flow of more massive ions towards the cathode remains unimpeded. The low voltage and suppressed electron flow minimizes x-ray bremsstrahlung emission, allowing successful operation, in the accelerator environment, of state-of-the-art monochromators with fiber optic outputs and photomultipler detectors.

Ion and Neutral Velocity Distributions in the Anode Plasma. Observation of the Doppler broadening of spectral lines as a function of time and distance from the anode substrate, in a parallel direction to the anode surface, provides the ion and neutral velocity distributions in the anode plasma (Maron et al., 1989a). Conventional fused silica optics, and the entrance slit to the spectrograph, provide 0.3 to 0.9 mm spatial resolution. Tracers such as Mg, B, and Si planted at selected locations in the epoxy of the anode, allow further spatial resolution. A grating (2400 lines mm^{-1}) 1-m spectrograph with a cylindrical output lens feeding nine photomultiplier tubes through rectangular fiber optic bundles, provides a spectral resolution of 0.1 Å and a temporal resolution of 5 ns.

The spectrograph records lines selected for negligible pressure and Zeeman broadening insuring the dominance of Doppler broadening. The measured velocity distributions are nearly Maxwellian with temperatures of 8 eV for the neutrals, 20 eV for singly charged ions, and 20-80 eV for multiply charged ions. This observation holds for carbon, main constituent of the epoxy and the Mg, B, and Si tracers as well.

Measurements perpendicular to the anode should reveal temperature-broadened Doppler shifted lines due to the directed ion velocities. The large gradients in the perpendicular direction in the plasma, cause difficulties in the interpretation of this measurement. Spectral line shapes reveal velocity distributions consistent with the positive half of the Gaussian distribution characterized by the same temperature that was measured in the transverse direction.

Light emission is first observed at 20 ns. At 55 ns the plasma has reached a thickness of 1.5 mm, suggesting expansion velocities, independent of the applied magnetic field, of 3 to 5 cm μs^{-1}.

Measurements of Electron Density. Broadening of the Hβ line through the Stark effect, allows a measurement of the electron density. Space-resolved electron densities have typical values of 2.0E + 15 cm^{-3} in the bulk of the plasma and 3.0E + 15 cm^{-3} closer to the substrate surface.

Determination of Electron Temperatures. The determination of the electron temperature (Maron et al., 1989b) in the anode plasma is substantially more difficult because the relative populations of excited levels, which are normally used to determine electron temperatures, are far from equilibrium, and depend on the electron density. Analysis of the data is further complicated by a material flow from the anode substrate into the plasma.

The Weizmann Institute group has chosen to attack the problem directly by observing the line intensities as a function of time and comparing these intensities with those calculated from a time-dependent collisional radiative code that predicts the time-dependent populations of the atomic levels, while taking into account the continuous supply of substrate material to the anode plasma. To remove the ambiguities that arise from shot to shot variations two spectroscopic systems were used to measure simultaneously the intensities of two lines in the same discharge.

The time-dependent collisional radiative code utilizes the time-dependent electron density and a time-dependent supply function for material from the anode substrate as input parameters. The absolute intensities of the lines are assumed to follow this supply function. The self-consistent calculation proceeds by assuming a time-dependent electron temperature (assuming a Maxwellian velocity distribution for the electrons) as input parameter. Ionization and radiative three-body collisions couple adjacent atomic/ionic species while electron collisional excitation and deexcitation couple atomic levels within each species. The time dependence of the electron temperature is then adjusted until the calculated intensity ratios agree with the measurements.

The supply function severely affects the relative level populations early in the pulse. Fortunately the supply function plateaus when the power pulse peaks. Equilibration between levels for a given ionization state is sufficiently fast to allow the electron temperature to predict what the level populations should be. Electron temperatures that best fit the intensity ratios corresponding to the CIII, MgII, and AlIII levels are between 5 and 8 eV. Intensity ratios corresponding to the CIII levels suggest a flat temperature profile across the plasma.

Determination of Particle Fluxes. The injection rate of neutrals and ions into the plasma (Maron et al., 1989c) is obtained from measurements of the absolute intensities of spectral lines. The electron temperature and density are high enough to quickly ionize the material that flows from the substrate into the plasma. The ionization probably results from electron impact ionization of neutrals released from the surface. The increase of electron density across the plasma is consistent with this ionization process that produces the multiply charged ions and protons that reach the ion-emitting region.

Heating of the ions, once they reach the plasma, is likely to take place through the large electric fields that exist at the plasma/substrate interface. Neutral kinetic energies, on the other hand, can probably be explained by charge exchange collisions between energetic ions and neutrals.

The process of neutral release, from the substrate into the plasma, is not understood at this time and will require careful investigation in the future.

Determination of the Time-Dependent Magnetic Field. The time-dependent (Maron et al., 1989d) magnetic field in the plasma was obtained from a measurement of the Zeeman splitting of lines of BaII purposefully seeded in the plasma.

The diode magnetic field, present in the plasma very soon after the plasma is formed, suggests that the ionization of an expanding neutral layer forms the plasma with the magnetic field in place. The magnetically insulated current that flows in the gap in an E x B direction also gives rise to a magnetic field that is observable. The penetration of this magnetic field is a diagnostic to determine the conductivity of the anode plasma. Since the penetration is much faster than what classical conductivity would predict, according to Maron, enhanced electron collisions arising from a lower drift instability must be present. A lower conductivity also explains the fast expansion of the plasma into the applied magnetic field and the uniformity of electron temperature in the plasma.

Summary and Conclusions

Spectroscopic diagnostics yield very important insights on the physical processes that take place in the anode plasmas in high-power ion diodes. The richness of the results surpasses the difficulties encountered in obtaining, reducing, and interpreting the data. It is quite remarkable that what I have summarized is the product of only 2 years of experimental work and data reduction.

To quote Pace VanDevender, leader of the ion beam fusion effort at SNLA (VanDevender, 1988), referring to Professor Maron's presentation at Beams '88 (Maron et al., 1988):

> "The spectroscopic diagnostics presented by Prof. Maron are spectacular. He has measured almost everything in the diode: fields, particle velocities, and particle distributions. The anode plasma proved to be very complicated. But the diagnostics let Prof. Maron observe the evolution of H, H+, C++, C3+, and use the non-equilibrium collisional-radiative model to understand the abundance of protons with time and position. This picture of the anode plasma looks pretty messy. Developing a better ion source should be a major goal for the coming year.
>
> Spectroscopy has led to a precise measure of the ion kinetic energy versus the distance from the anode. The measurements verify the uniform electron distribution we have assumed to explain the enhanced ion current observed in ion diodes. That quality of data and corresponding understanding has advanced diode physics from phenomenology to science."

In summary, the development of new diagnostic tools for ion diode plasmas has taken place in three phases:

- Reliable acquisition of high resolution and accurate data
- Construction of a theoretical framework for analysis of the data
- Construction of models that incorporate the data to understand highly dynamic nonequilibrium plasmas.

These tools are now ready to be applied to plasmas in other pulsed-power systems. They will be applied by this group, in the near future, to the study of plasmas in PEOS. These are important components of accelerators used in the particle beam fusion effort. Knowledge of the time-dependent plasma composition and the diffusion of the magnetic field in the plasma of PEOS will be very helpful to resolve long-standing controversies on what the mechanism of switch opening really is.

Similarly, these methods will be very useful in the study of current sheets of imploding plasmas that produce high energy densities in matter. As in the case of diode anode plasmas discussed above and in the case of the PEOS, understanding of the processes of ionization, plasma heating, and diffusion of magnetic field in the plasma are essential to future improvement of these devices.

Professor Maron and his group are already applying his diagnostics at other laboratories. For example, SNLA

has obtained line profiles and intensities from anode plasmas in the diode of PBFA-II. The 50-m-long optical fibers, shielded near the diode to prevent x-ray scintillation, carry the signals to a remote monochromator. Preliminary indications are that light attenuation, even in the UV is manageable. Professor Maron now looks forward to the analysis of the data. He also looks forward to investigate, in collaboration with the Naval Research Laboratory, the properties of plasmas in PEOS.

References

Maron Y., et al., "Particle Velocity Distributions and expansion of a Surface Flashover Plasma in the Presence of a Magnetic Field," to appear in *Physical Review A*, (1989a).

Maron Y., et al., "Electron Temperature and Heating Processes in a Dynamic Plasma of a High Power Diode," *Physical Review A*, (1989b).

Maron Y., et al., "Spectroscopic Determination of Particle Fluxed and Charge State Distributions in a Pulse Diode Plasma," *Physical Review A*, (1989c).

Maron Y., et al., "Time-dependent Spectroscopic Observation of the Magnetic Field in a High Power Diode Plasma," *Physical Review A*, (1989d).

Maron Y., et al., "Spectroscopic Investigations of the Non-Equilibrium Plasma and the Charge Flow in Ion Beam Diodes," paper AI3, in *Proceedings of the 7th International Conference on High Power Particle Beams*, (1988), 57-68.

VanDevender, P. "Beams 88 Panel Presentation," paper ZP1, in *Proceedings of the 7th International Conference on High Power Particle Beams*, (1988), 1499-1503.

2/7/89

Pulse Power Facilities and Flash Radiographic Facilities of France's Commissariat a L'Energie Atomique - Direction des Applications Militaires

by Marco S. Di Capua.

The Division of Military Applications (DAM) of the French Atomic Energy Commission (CEA) has been supporting a substantial pulse power effort at two sites since the early 1970's. One site, at Moronvilliers, near Reims, emphasizes flash radiography and high-speed hydrodynamic measurements on dense media. The other site, at Valduc (near Dijon) was functional until June 1988 when operations were transferred to the Centre de' Etudes Scientifiques et Techniques d' Acquitaine (DAM CESTA) at Le Barp (near Bordeaux) as part of the Experimental Physics Section. Other laboratories belonging to CEA-DAM are at Limeil, Bruyeres le Chatel, and Tours.

The Le Barp site now operates bremsstrahlung and imploding plasma x-ray generators for vulnerability studies, electron beam generators for thermostructural response and equation of state research, and two new generators devoted to linear induction accelerator (LIA) and free electron laser (FEL) research (see page 46, above).

I was a guest of the CEA DAM in January 1989 at Moronvilliers and Le Barp. My report describes the facilities I visited and the research we discussed.

The Moronvilliers Facility

The Moronvilliers facility is a remote test site of the CEA DAM Centre d'Etudes de Vaujours-Moronvilliers. This center has two locations, an urban one, situated at Vaujours near Courtry, a northeastern suburb of Paris; and a remote one, in the Champagne agricultural region. The remote site is near the village of Moronvilliers, about 15 km northwest of Reims in a hilly promontory, cut by deep ravines. Deep craters and trenches mark the terrain of this promontory, heavily shelled by French forces during WWI campaigns. Seventy years after the end of the hostilities live explosives are still being discovered as the site is upgraded and improved.

About 10 explosive test facilities are scattered throughout the site. These facilities have flash radiographic generators, steel firing tables, and steel and concrete bunkers, that house high-speed diagnostics to investigate the processes that take place when dense metals accelerate, driven by the detonation of high explosives.

Experimental measurements are obtained through conventional diagnostics such as:

- High-speed rotating mirror cameras (1.0E + 06 frames s^{-1})
- Shorting pin assemblies connected to digital counters (100 ps to 5 ns resolution) to measure the time of arrival of shock waves and the speeds of free surfaces inside metal shells
- Interferometers with pulse lasers to measure velocities of a few times 1.0E + 03 m s^{-1}.

More advanced (photonic) diagnostics are available such as fiber optic assemblies that replace the shorting pin assemblies for time of arrival measurements. These diagnostics consist of a very small nitrogen volume coupled at the end of an optical fiber (Vicar et al., 1984). The sudden compression of the nitrogen produces a flash of visible light. The light output from the optical fibers, is coupled to the slit in the faceplate of a Thomson CSF 503 streak camera. where one piece of film records the time of arrival of a shock at 52 different locations. The CCD arrays, slated to replace the film in the near future, will allow direct acquisition of the data in digital form.

Flash radiographic facilities at Moronvilliers. The flash radiography facilities at Moronvilliers, supervised by Jaques Buchet from Vaujours, freeze the motion, very much like a stroboscope would, of rapidly-moving, dense objects. Flash radiographs of metals flowing in very high pressure fields, generated by high explosives, allow physicists to:

- Visualize contours
- Observe jetting and spallation
- Measure densities
- Observe cracks that appear when metals stretch

Flash radiographs also reveal detonation, shock, and expansion waves in high explosives.

Flash radiographic facilities at Moronvilliers. The largest flash radiography facility at Moronvilliers, installed in early 1975, is the Generateur de Radiographie Eclair (GREC). GREC is a 7-MV, 35-ohm oil Blumlein electron accelerator. Electrons from GREC, striking the 15- to 20-mm-diameter focal spot in a tantalum bremsstrahlung converter, routinely produce a maximum x-ray dose of 550 R at 1 m, with a mean energy of 3 MeV. These x-rays can penetrate materials with an areal density up to 200 g cm^{-2} and resolve velocities as high as a few millimeters per microsecond.

The x-ray film stacks, loaded in cassettes protected by 20 to 30 gm cm^{-2} of steel armor, record the radiographs. Collimators, in front of the cassettes, add another degree of blast protection while attenuating scattered radiation.

Two evolutionary steps have quadrupled the dose of x-rays. The addition of a magnetically insulated vacuum transmission line (MITL) (Guix et al., 1985) between the vacuum envelope and the cold cathode emission diode first doubled the dose. Acting as a capacitive divider, the MITL reduced the electrical prepulse, a cause of anode plasma formation, that results in early closure of the gap of the diode. Most recently, the dose was again doubled to its present value of 550 R at 1 m by the addition of plasma erosion opening switches (PEOS) (Neri et al., 1987). These switches are placed between the vacuum envelope and the entrance of the 150-ohm MITL. The combination of PEOS and MITL has been extremely successful in reducing the prepulse resulting from the charging of the Blumlein pulse forming network.

The physicists that use the facility (under the direction of H. Biero) have found that reproducible operation of the PEOS requires a very strict quality control in the cleaning of the plasma sources (Mendel et al., 1980), their treatment with colloidal graphite, and their preconditioning in anticipation of a radiographic shot. They have also found that diodes with titanium foil anodes produce smaller anode focal spots than with aluminum foil anodes. This suggests that the anode plasma, as a source of ions, plays an important role on the behavior of the pinched diode.

The most recent upgrade of the facility consists of the addition of new tunnel complexes, fireproof doors, fiber optic cableways, bays for diagnostic trucks, etc., giving me the impression of a well-capitalized, well-maintained, no-frill, safe, compact, up-to-date working installation.

The operators regret, as it happens in many other user facilities, that, due to large user pressure, they have little time to carry out research that would lead to further dose improvements or would result in a smaller focal required to increase resolution.

Another radiographic facility is ARTEMIS (Hauducoeur et al., 1985), an acronym for the French words that mean: three-exposure-multiimage-radiographic-accelerator. It has been operational since the latter half of 1984. The 10 MV m^{-1} gradient, 1.3 GHz traveling wave electron accelerator, produced by the French company CGR MeV, has a modulator-driven cathode. The electron beam, with a maximum current of 60 A and energy of 45 MeV, strikes a 2-mm-thick W target that converts the electron kinetic into x-ray bremsstrahlung radiation with a 3-mm-diameter focal spot.

The accelerator has two operating modes. It can produce up to 15 pulses of 30- to 100-ns duration (in a 18-μs window) with a dose of 30 R at 1 meter (50-ns pulse duration) in one mode. In the other mode it can deliver a single 15-μs pulse with a dose rate of 30 R μs^{-1}.

A fast scintillator (Alustipe Blue 155) converts the x-ray image into 450-nm blue light that is imaged by disposable optics (mirrors and cardboard tubes) through 600-mm f/.4 objective lenses onto three ITT-F 4113 image intensifier tubes. A fiber optic relay conveys the image to a Thomson CSF 7882 CCD array. In the streak mode, the intermediate image intensifier relays the light to a TSN 506 streak camera.

I was shown two exquisite cineradiographs (three exposures each) of an imploding cylinder with a scalloped inner surface. As the cylinder implodes, the scallops generate jets that squirt inward as the radius of the cylinder decreases. The resolution was sufficient to reveal the original shallow scallops as well as the evolution of the thin jets jutting into the interior as the cylinder implodes.

A radiographic facility with such high electron energy has two main drawbacks. One is that the x-ray spectrum is so hard that Compton diffusion associated with pair production causes blur in the radiographs. Consequently special procedures are necessary to deconvolve the density data from the images. The other is that the x-ray energy is above the energy for maximum transparency of the metals under study and the efficiency of the detectors due to the high energies involved is quite low. As a result, optimization of this linear accelerator cineradiography system has been a very exacting task.

At the other end of the spectrum, the third radiographic facility is MEVEX, which produces 1.2 R at 1 m with an 800-kV, 30-ns-long electron pulse collapsing into a 4-mm-diameter focal spot on a tantalum converter. This accelerator is devoted to detonics research and fundamental hydrodynamics experiments.

The 60 gm cm^{-2} armor required to shield the film cassettes limits the effectiveness of MEVEX so the Moronvilliers site is now procuring a new 3 MV, oil-dielectric accelerator that will most likely achieve a very small focal spot with a foilless diode and magnetic compression of the beam.

The CESTA Laboratory

The CESTA laboratory is situated 35 km southeast of Bordeaux near the village of Le Barp. This laboratory performs environmental and vulnerability testing on space hardware for the CEA, other French government agencies, and the French aerospace industry. The environmental testing facilities comprise centrifuges, drop towers, impact facilities, and environmental test chambers. Vulnerability testing facilities expose military components and assemblies to photon and electron fluxes to reveal difficulties that would arise under nuclear threat operating conditions.

I visited the experimental physics division of CESTA as a guest of Dr.Christian Jaussein, the division leader. This division incorporates, in the physics of high energy pulses (PHEP) section, the facilities that have been transferred from Valduc except for SIDONIX, which is decommissioned. In order of year of commissioning, these facilities are: EUPHROSINE (1970), THALIE (1974), AGLAE (1982), AMBIORIX (1987), and CESAR (1989).

Pulse power facilities of the PHEP at CESTA. THALIE is a flash gamma simulator with a 30-ohm Blumlein pulse-forming section that delivers 120-kA of 10-MeV electrons in a 70-ns-wide pulse. It delivers a dose rate of 1.0E + 11 Rad(Si) s^{-1} at 1 m with a mean energy of 2 MeV. The users' area of this accelerator now has improved radiation shielding, and up-to-date customer support facilities such as new screen rooms and cable trunks.

AGLAE is a four-stage water dielectric accelerator (Bernard et al., 1983; Bruno, 1988) with a 0.6-ohm final impedance. It drives imploding plasma loads with a 1.6-MA, 45-ns current pulse. The imploding plasma (Bailly-Salins, 1988) produces more than 1 kJ of line x-ray radiation with an energy above 1 keV. Spectra have been recently obtained of H-like and He-like Ne as well as He-like Argon. The composition of the plasma deserves further investigation as in the case of other plasma devices (see page 54). At present, there is a discrepancy between the mass in the puff determined by interferometry and the mass that fits measured velocities in a dynamic model of the pinch. Streak camera records show that the luminosity of the pinch appears first at the cathode side and only later at the anode side. This effect, observed at other laboratories, is known as the zipper effect (Stringfield, 1984).

AMBIORIX is a low-impedance (0.5-ohm) triaxial water transmission line accelerator that drives a bremsstrahlung-producing, cold-cathode emission diode. Ambiorix delivers a 2-MA, 1-MeV pulse of electrons to a cylindrical anode and provides a dose of 5.0E + 11 Rad(Si) s^{-1} of x-rays with a 200-keV spectrum at a distance of 10 cm.

CESAR, their newest facility, has a 100-kJ 3.4-MV Marx generator that charges a 3.4/2.0-ohm transfer capacitor, followed by a 1.4/2.0-ohm pulse forming line that connects, through gas prepulse switches housed in an epoxy slab, to a 2.0/1.0-ohm output line. The vacuum envelope is a multistage tube with field grading rings. The cold cathode diode and electron beam transport system of Cesar will deliver 3000 cal/gm to a target to obtain equations of state of materials at pressures as high as 200 kbars. At this moment, the beam transport system, consisting of a gas cell and beam guiding solenoid magnets, is under development under the direction of J.M. Angles.

EUPHROSINE is presently being redeveloped by J. Launspach to perform research on high-brilliance electron beam injectors for LIA FEL drivers. It has a 30-ohm oil output line that delivers a 60- to 70-kA 60-ns-wide pulse. The diode, under development, has a thermionic cathode. An intermediate electrode and converging magnetic fields will focus the 30-A cm^{-2} electron beam to a current density of 1-3 kA cm^{-2}. Carbon resistors connecting successive field grading rings, shunt the excess current of the accelerator on the oil-side of the vacuum envelope. The diode configuration, which is now ready for testing, is designed with the SLAC EGUN code (Herrmannsfeldt, 1979). There are plans to perform numerical

studies of the diode using the SAIC MASK (Drobot, n.d.) particle-in-cell code which is expected to be available at the CEA-Limeil computing facility in the near future.

The newest facility at CESTA is a magnetic energy compression generator (Baudoin, 1988) that will produce short (80 ns), high-voltage (150 kV) pulses to drive a LIA. Since this is a new field of activity for the CEA a purpose of the program is to develop competence in the field of magnetic switching and to learn the technology of LIA's.

The main components of the modulator are a:

- 30-kV power supply.
- 2-μF storage capacitor
- 1-10 step-up transformer
- 20-nF water capacitor
- Magnetic switch
- 2-ohm, 40-ns water-dielectric pulse-forming line
- Output magnetic switch
- Load comprising 24 50-ohm output cables.

Initially the magnetic switches were toroidal metallic glass cores supplied by the West German firm Vacuumschmeltz (in Frankfurt). These cores have a thin MgO insulating layer. The first stage magnetic core performed up to specifications. The output core did not, and insulation breakdown due to the fast risetime pulse is the suspected cause for the slow risetimes that were observed at the output. A Mylar-insulated core is presently on order from Allied Metals in the US and a research program to replace MgO by SiO_2 is also presently under way.

Conclusions

The facilities I have described are a testimony to a strong technology base development program at the CEA. Substantial capital improvements, as well as personnel development programs presently under way, will provide the CEA with up-to-date facilities and state-of-the-art technology. This places the CEA at the forefront of mission- oriented of hydrodynamic and pulse power research and development.

The CEA has established a policy of consolidation of facilities (a good example is the consolidation of the efforts of Vaujours and Moronvilliers and the transfer of facilities from Valduc to Le Barp). As explained to me, CEA's management greatly desires to maintain the momentum of innovation by encouraging mobility of personnel between projects and mobility of projects between laboratories (see page 67). This viewpoint runs against European tradition where, until very recently, mobility has been considered a liability. The personnel I spoke to feel that while on the short run the CEA policy may be stressful, from personal as well as from professional viewpoints, in the long run, it will benefit the projects and contribute to the professional development of the technical staff.

References

Bailly-Salins R. et al., "Temporal Development and Radiation of Imploding Cylindrical Plasmas," Paper UP 8, *Proceedings of the Seventh International Conference on High-Power Particle Beams*, KfK Karlsruhe, FRG (1988), 1210-1215.

P. Baudoin, "Magnetic Modulator for Driving a Linear Induction Accelerator," same as Bailly-Salins, Paper SP5, (1988), 1079-1083.

Bernard, A. et al., "The AGLAE Facility at Valduc," in *Proceedings of the 4th IEEE Pulsed Power Conference*, Albuquerque, New Mexico (1983).

Bruno, C., et al., "Plasma Erosion Opening Switch Experiments," same as Bailly-Salins, Paper TP1, (1988), 1109-1112.

Drobot A., *The MASK Particle in Cell Code*, a product of Science Applications International Company (SAIC), McLean, Virginia 22102

Guix R. et al., "High Energy Flash X-ray Generator: GREC – New Performances," *16th International Congress on High Speed Photography and Photonics* (Strasbourg, 1984), also in: *Proceedings SPIE*, Vol. 491, (1985), 144-152.

Hauducoeur A. et al., *ARTEMIS Facility for Cineradiography at High Energy*, Paper 491-19, CEA DAM, Vaujours (1985).

Herrmannsfeldt, W.B., *Electron Trajectory Program*, Report SLAC-226, Stanford Linear Accelerator Center, Stanford, California (1979).

Mendel C. W. et al., "Carbon Plasma Gun," *Review of Scientific Instruments*, Vol. 51, (1980), 1641-1644.

Neri F. M. et al., "High Voltage High Power Operation on the Plasma Erosion Opening Switch," *Applied Physics Letters*, Vol. 50, (1987), 1331.

Stringfield R., *The Zipper Effect*, Report PIIR-84-XX, Physics International Company, San Leandro, California (1984).

Vicar L. R. et al., "Microshell Tipped Optical Fibers as Sensors of High Pressure Pulses in Adverse Environments," *Fiber Optics in Adverse Environments II, Proceedings SPIE*, Vol. 506, (1984), 116-121.

2/14/89

Switzerland's Nuclear and Chemical Warfare Laboratory at Spiez

by Marco S. Di Capua.

Overview of the Laboratory

The Nuclear and Chemical Warfare Laboratory (NC) – also known as the AC Laboratorium – in Spiez, Switzerland, belongs to the Defense Technology and Procurement group of the Swiss Common Defense Organization (Ministry of Defense). In 1974, it was tasked to assist with protection measures for the survival of the army and population in case of atomic and chemical warfare. This assistance takes two specific forms. One is the training of specialists and cadres within the voluntary armed forces on the threats of, and means available for protection against, atomic and chemical warfare. The other is operation of a laboratory to develop protection devices adequate to the threat. Since the administration of civil defense for the population as a whole rests within the Ministry of Justice and Police the tasks of the NC Laboratory are limited to:

- Performing applied research in protection from nuclear and chemical warfare, including the development of protection measures
- Advising the military and civilian sectors on means of protection, including testing of protection measures at threat levels
- Training of defense personnel on protection measures.

In addition to its support groups, the NC Laboratory has three main departments:

- The Physics Department, whose activities encompass fundamental calculations on nuclear weapons (NW) output and effects, radiation physics and radiation protection, the effects of thermal radiation and electromagnetic pulse (EMP), the effects of blast and shock, and the physics of aerosols
- The Chemistry Department, which deals with organic chemistry biochemistry, toxicology and pharmacology, analytical chemistry, applied chemistry and decontamination, physical chemistry, and filtration techniques
- The Engineering Department, which develops and tests individual as well as collective means of protection, equipment, and materials.

The Swiss Confederation takes the threat of nuclear and chemical warfare – and hence, civil defense – very seriously. New construction, by law, must provide a shelter for the residents and the NC Laboratory is responsible that shelter equipment such as blast doors, blast valves, filters, radiation detectors, two-way radios, generators, etc. will respond satisfactorily to a specified threat. It also develops and tests protection measures for the country's command posts, arms and ammunition depots, tunnels, railways, etc.

My interests at the NC Laboratory concerned the work of the Physics Department. As a guest of the director of the department, Dr. Max Keller, I can describe its activities in some detail.

Activities of the Physics Department

The goal of Dr. Thomas Rudy, who performs fundamental calculations on NWE, is to provide quantitative, time-dependent estimates of the output of a nuclear explosion. Specifically, he wants to obtain, from first principle, the weapon output curves that appear in the book by Samuel Glasstone, *The Effects of Nuclear Weapons*. This includes incorporating absolute magnitudes where these have been omitted. He is accomplishing this task in two steps. The first step, is to derive from first principle the radiation output (gamma dose and gamma dose rate) of a nuclear assembly. The second step is to couple these results to a code that calculates the fireball, and blast-wave development and propagation. Codes for this second step are available from commercial sources.

To calculate the output of a nuclear assembly, he has modified the AX-1 code (Okrent, 1959). It was developed at ANL to simulate, at low pressures, the hydrodynamics and neutronics of the Los Alamos National Laboratory (LANL) Godiva critical assembly. The Federal Institute of Technology (ETH) in Zurich improved the hydrodynamics, and modified the equation of state (EOS) sections for high pressures so that the new code, SHYRAN (Spherical Hydrodynamics with Radiation Transport and Neutronics), now calculates the time behavior of a spherical nuclear device from the beginning of the compression by high explosive to the disintegration of the material. As a next step, Dr. Rudy will incorporate the effect of neutrons produced by fusion reactions in a DT fill at the center of the assembly to increase the reaction rate of the fissile shell surrounding it. The group has ties with the Paul Scherrer Institute (PSI) in Villigen (Drs. Walter Fischer, leader of the Neutron Spallation Source, and Andreas Pritzker).

Dr. Rudy stressed that Switzerland, which strictly abides to the NPT (Nuclear Proliferation Treaty), does not intend to make technical calculations or even plan tests. His calculations or even plan tests. His calculations serve to extend their knowledge of fission assemblies for a better understanding of the actual threat.

Research in aerosols concerns the effectiveness and particulate retention (long-term behavior) of filter materials. The research is conducted in apparatus that can produce aerosols and detect particles with sizes in the range of 5 to 500 nm. The physics of retention is quite interesting since it contains elements of fluid mechanics and surface physics. It appears that, for a given flow velocity, the capture ratio of a given filter material exhibits a minimum for a certain particle size. The reason for this behavior is that the larger particles, that do not follow the streamlines, get captured by the filter matrix while the smaller particles undergo Brownian motion and only undergo capture as they hit the filter fibers. Therefore there is a particle size, for a given filter material and flow velocity, that exhibits a minimum capture probability. Such a particle is small enough to follow the streamlines but too big to have a large mean free path when it undergoes Brownian motion. At larger flow velocities for a given filter, more and more smaller particles get through. The laboratory has developed precise protocols for filter testing that deliver reproducible results, and it is the organization that performs acceptance tests on filter materials acquired by defense organizations.

A small radiochemistry group identifies, through high-resolution gamma spectroscopy, radionucleides in complex mixtures and supports the regional military laboratories and cantonal chemists with difficult identifications. The group is still performing research on the flow of Cs 137 from the Chernobyl accident through the ecological chain in a highly eutrophied lake, with a small water exchange, at the bottom of a valley. The valley was exposed to rain on the day the radioactive cloud flew over. As a consequence, the lake has retained a substantial amount of radioactivity, and fish, that metabolize Cs 137 at a slower rate than mammals, are still very radioactive. I did not obtain the magnitude of current activity.

The EMP group operates EMP testing facilities for Swiss government and industry customers. The group operates:

- A US-made (Physics International Company) outdoor mobile EMP simulator that provides a 200-kv m^{-1} horizontally polarized electrical pulse (4 MV, 20 m above ground) with less than a 10 ns risetime. Airplanes, locomotives, tanks, trucks, and boats have been tested at this facility
- A US-made (Physics International Company) current injector (150 kV into 5 ohms) tests cable connections, grounding leads, and closure seals
- A parallel-plate transmission line generates a vertically polarized 100-kV m^{-1} electric field in a test volume of a few cubic meters. It is used mainly to test communications equipment. Dr Carl Baum of the Air Force Weapons Laboratory, Albuquerque, New Mexico, collaborated in the design of the facility
- Screen rooms and data acquisition systems support these facilities.

The EMP theory group under Dr. P. Mani is developing electromagnetic codes in the OCCAM language that will run in an INMOS T 800 transputer (a mini supercomputer; see *ESNIB* 88-03:33-35). These codes are expected to be operational in 1989.

The facilities of the blast and shock department are used to test shelter equipment and accessories. A shock tube that reaches equilibrium pressures as high as 9 bar tests the self-closing blast valves that protect particle filters and prefilters for shelters. The Spiez laboratory will test some of these valves in a buried concrete structure in the Misers Gold event that will measure effects of a 4000-ton ammonium-nitrate/fuel-oil explosion.

A gravity-propelled cart that stops on impact with a copper bumper decelerates loads as massive as 3.5 T at 16 G. It simulates air slap accelerations from a nuclear burst. A hydraulic table, capable of 16-G vertical acceleration is being commissioned at present. Both these facilities qualify shock mounts as well as equipment at threat levels.

Conclusions

The NC Laboratory provides, within well-chosen boundaries, state-of-the-art simulation facilities for effects of NW and chemical weapons. The lack of access to NW-effects data bases has encouraged them to develop their own data. This includes calculations on fissile assemblies.

Reference

D. Okrent et al., *AX-1, A Computing Program for Coupled Neutronic hydrodynamics calculations on the IBM 704*, ANL report ANL-5977, (1959).

1/16/89

Electromagnetic Launcher Research at the French German Research Institute (Saint Louis)

by Marco S. Di Capua.

A new electromagnetic launcher (EML) research program under the leadership of Dr. F. Jamet (Wegner et al., 1988; Jamet et al. 1988) has been initiated at the French German Research Institute Saint Louis (ISL) (see *ESNIB* 89-03:40). The program will perform fundamental research on acceleration of projectiles with electromagnetic forces. In an EML, the projectile slides along two electrodes (called the barrel) pushed by magnetic pressure exerted in a plasma conductor (called the armature). ISL will investigate:

- The plasma properties of the armature
- Physical processes which take place at the plasma-barrel contact (with emphasis on electrode erosion)
- Friction in the projectile-barrel interface
- High-power semiconductor (Thyristor) switching.

The intention of the program is to capitalize on the large and sophisticated ISL diagnostic capability. The program does not address EML applications as Strategic Defense Initiative launchers or applications to equations-of-state studies.

A new EML experimental facility, which has been in service since mid-1988, consists of a 9.2-mF, 10-kV capacitor bank equipped with ignitron switches and a modular series storage inductor to limit the peak current in the circuit. Initial experiments (Jamet et al., 1988) performed with 330 kJ in the bank (8.5-kV charge voltage), a time to current peak of 240 μs and a peak current of 420 kA accelerated a 3.2-g projectile from an initial velocity of 1 km s^{-1} to an exit velocity of 2.8 km s^{-1}. A careful accounting of energy losses justifies a global efficiency of 3.7 per cent for the system.

A very exciting development in the ISL program will be the substitution of the ignitron switches used in the present EML with high-power thyristors supplied by the semiconductor division of ASEA Brown Boveri (ABB) (Vitins et al., 1988). A modular thyristor array, based upon commercially available 6 kV, 2000 A units will be tested shortly.

Future plans for the EML facility consider a 10 MJ capacitive distributed energy store to deliver electrical power at successive times and positions along the barrel. This "traveling wave" arrangement will optimally accelerate a 50-mm-caliber projectile with a maximum mass of 200 g to velocities of 5 km s^{-1}. The proposal for this facility is under consideration by the ISL administrative board, and if approved, could be in operation in the next 3 to 4 years.

References

Wegner, V. et al., "Electromagnetic Acceleration Activities at the French-German Research Institute Saint Louis (ISL)," in *Proceedings of the 4th Symposium on Electromagnetic Launcher (EML) Technology*, Austin, Texas (1988).

Jamet, F. et al., "Experimental Results Obtained with the ISL 500 kJ Railgun Facility," in *Proceedings of the 1st European Symposium on EML Technology*, TNO Delft, Netherlands (1988).

J. Vitins et al.,"High Power Semiconductors for Pulsed Switching," *Proceedings of the 1st European Symposium on EML Technology*, TNO Delft, Netherlands (1988)

2/13/89

NEWS, NOTES, AND ABSTRACTS

Overseas Liaison Scientist Positions – Tokyo, Japan

The Office of Naval Research, the Air Force Office of Scientific Research, and the Army Research Office are jointly soliciting letters of interest and resumés from qualified candidates to fill liaison scientist positions in their combined office in Tokyo. Candidates are sought who are US citizens, are currently research scientists or research engineers, and who have a Ph.D. or equivalent experience in physical, environmental, engineering, or life sciences. In general, preference is given to candidates from the academic or government sectors. Knowledge of DoD R&D activities, relevant established foreign contacts, and stature in the international R&D community are highly desirable features of an applicant's background.

Generally, up to 2-year assignments are available for coverage of the following fields (periods are somewhat negotiable):

Computer Science (continuing requirement)

Electro-optics/lasers
Materials/composites/ceramics
Chemistry/polymers
Biotechnology
Solid State Electronics
Manufacturing Science
Statistics/Applied Math

Liaison scientists survey research in selected areas of importance to current or potential R&D interests of the sponsoring offices. They interact with foreign scientists via personal contacts and attendance at meetings and write interpretive reports of their survey efforts.

Candidates should send letters of interest (indicating dates of availability) and resumés to: Ms. Pearl Cano, Office of Naval Research, International Programs (Code 11D5), Arlington, Virginia 22217-5000.

A Course on Noise Reduction of Machinery Installations

A course entitled "Noise Reduction of Machinery Installations by Vibration Isolation" will be offered at Noordwijkerhout, the Netherlands, during the period from 23 through 27 October 1989. This course will provide engineers with the latest information from applied research and seeks to improve their knowledge and understanding of structureborne sound isolation. The knowledge gained has many practical applications to a wide range of industrial products. These include amongst others aircraft, motor vehicles, railway vehicles, processing plants, buildings, and consumer products.

The course has been prepared by a group of individuals from European organizations with the support of the European Community action program for Education and Training for Education and Technology (COMETT). Course instructors have been recruited from the TNO Institute of Applied Physics (TPD), Delft, the Netherlands, the University of Southampton Institute of Sound and Vibration Research (ISVR), UK, and Metravib RDS, Lyon, France.

The instructors, all recognized internationally known experts in their fields, will present the course over a 4-day period with course lectures, case histories, and laboratory demonstrations. The demonstrations will take place at the TPD laboratories in Delft.

The course lecturers are:

- Dr. J.G. van Bakel, head of the Research Section of the Ship Acoustics Department TPD
- Dr. B.J. Dobson, Senior Consultant in the ISVR University of Southampton
- Dr. B. Garnier, head of the Vibration Group at Metravib
- Professor J.W. Verheij, Senior scientist and part-time professor at Eindhoven University
- Professor R.G. White, Director of ISVR and Professor of Vibration Studies
- Dr. T. ten Wolde, head of the TPD Acoustics Division

The enrollment fee for the course is Dfl 3515 (about $1650) and is all inclusive – i.e., includes lecture notes, meals and refreshments, accommodation, and taxes. Further information on the course can be obtained from: TNO Institute of Applied Physics, Administrator, Course COMETT, P.O. Box 155, 2600 AD Delft, the Netherlands.

Enrollment in the course should be completed by 22 September 1989 and, as the number of participants will be limited, prompt enrollment is advised.

David Feit
4/21/89

European Alliance in Molecular Biology of Ageing

During a recent meeting on Crete organized by EURAGE (the EC organization concerned with action on ageing and diseases), a collaborative network was established with the aim of jointly solving key problems in molecular biological research on ageing.

According to a release by the Netherlands Organization for Applied Scientific Research, the Crete meeting was meant to demonstrate the strength of European research in certain specific areas of molecular biological research on ageing and to formulate specific research targets suitable for an aggressive joint attack. For this purpose, subgroups have been formed. Within each subgroup research will be organized in a way that avoids duplicated efforts without excessive centralization. Sharing of research materials and the rapid frequent exchange of information is financed by EURAGE.

Another important decision taken during the meeting was to establish a joint research infrastructure so that the lack of certain research materials such as cell lines, biopsy material, certain DNA probes and antibodies, should never be a hindrance to anybody who would like to address a certain problem with a good technique. In addition, such facilities are relatively cheap to organize centrally, whereas they can be a burden to each individual laboratory and therefore form a hindrance to rapid progress.

EURAGE participants expect that their collaborative networks in the molecular biology of ageing will greatly stimulate research activities in this field; both public and private research funds will be made available in Europe. The major concern of the experts involved will be to increase the quality of the research being done and keep it at a high level.

For the time being, the collaborative network of the EURAGE molecular biology group will be coordinated by the TNO Institute for Experimental Gerontology.

C.J. Fox
3/29/89

Geophysical Mapping of the Dead Sea and the Sea of Galilee

A recent geophysical survey of the Dead Sea and the Sea of Galilee has revealed many new features of the subbottom structure in these areas according to a recent release from Tel Aviv University. These findings are the product of gravity measurements, carried out by Professor Zvi Ben-Avrham, Chairman of the University's Department of Geophysics and Planetary Sciences.

The survey was done with a marine gravity meter which was installed on boats in both lakes. The instrument measures small variations in the gravity field with an accuracy of one-millionth of the earth's gravity. Gravity measurements can detect variations in rock density and the thickness of sedimentary sequences.

The mapping process involved crisscrossing the bodies of water along a grid. The researchers were kept on course and given data on speed and direction by a Motorola Miniranger Navigation system on board the boat which received signals beamed from a series of land stations situated at precise locations on land.

The new gravimeter gave much information about the deep subbottom structure of the Dead Sea and the Sea of Galilee, which was until now very little understood. "The deep crustal structure of the Dead-Sea Galilee area revealed by our survey gives us information about the Dead Sea Rift on which these bodies of water sit," says Ben-Avraham. "Besides gaining valuable data on our main source of earthquakes, and providing significant information for oil exploration, we are learning a great deal about faults in the earth's crust. The Dead Sea Rift is very similar in tectonic setting to the San Andreas fault in California. They differ in that the average annual slippage in the San Andreas fault, which is a right-mov-

ing fault, is over 5 centimeters, while our plates are slipping leftwards at less than 3 centimeter a year. Our gravimetric data, which we are now analyzing, is giving us previously unavailable information about how our fault was formed, and how it is developing."

C.J. Fox
3/29/89

Repressing Memories of the Past Helps Holocaust Survivors

New research on sleep and dreaming indicates that people who have suffered a major traumatic experience in the past – like Holocaust survivors – cope better in later life if they actively deny and repress all memories of the event. This startling finding, announced in a Technion release, comes from an extensive study of Holocaust victims and their sleep patterns conducted at the Sleep Laboratory at the Technion-Israel Institute of Technology.

The results of the study directly contradict current treatment practices like those based on Sigmund Freud's theory of psychoanalysis. According to Freud, trauma victims should be encouraged to speak as much as possible about their experiences. Dreams, Freud felt, provide the "royal road to the unconscious." Therefore, the analysis of dreams plays an important part in treatment as dreams reveal the emotional damage caused by events too awful to face when awake.

And yet, the Technion study reveals that Holocaust survivors who were found to have adjusted well to postwar life not only recall their dreams far less than others in the study, but the dreams they do remember deal almost exclusively with trivial, everyday matters.

In other words, well-adjusted survivors have somehow managed to repress memories of the Holocaust, and, in fact, have almost no recall of their dreams at all.

The study, conducted by doctoral student Hanna Kaminer under the supervision of Professor Peretz Lavie who heads the Sleep Lab, involved 23 Holocaust survivors – 11 of whom were survivors of Nazi concentration camps, while 12 had spent most of the time in hiding or constantly on the move in fear of their lives – and a control group of 10 Israeli-born individuals who had no history of trauma.

After clinical interviews and a battery of psychiatric tests, the survivors were divided into two groups according to their adjustment to daily life and their coping style. By "coping style," the researchers were referring to how often vivid memories intrude or are avoided in the person's daily life or in dreams.

All subjects spent 4 nights at the Sleep Lab. Using polysomnographic recordings, their brain activity, breathing levels, rapid eye movements (REM) and leg movements were constantly registered. Results showed that ill-coping subjects suffered more from sleep disturbances as compared with the other two groups. But the most striking difference among the groups showed up in how many dreams they remembered.

During three of the nights, the subjects were awakened several times when they showed signs of dreaming, and were asked to recall their dreams. The Israeli-born subjects remembered eight to nine of ten dreams. The ill-coping survivors remembered about 61 percent of their dreams, and these were found to contain a high level of death anxiety and self-oriented hostility.

In sharp contrast, the well-adjusted survivors recalled their dreams only 30 percent of the time, and most did not recall dreaming at all. Furthermore, the few dreams they did remember were qualitatively different from the others in that they were shorted, devoid of emotional content, and dealt only with trivial everyday events.

These results indicate that the better-adjusted survivors were not allowing their memories of the Holocaust to intrude into their dreams.

Repression of memories also helped members of the well-adjusted group to cope in their daily lives. Most of them reported that they completely avoided talking about the Holocaust, even though they emphasized that they had never forgotten what they had undergone. In some, the suppression was so dominant that even their close relatives did not know of their experiences during the war.

Thus, suppression and repression used so effectively in daily life were also active during sleep. To avoid the risk of distressing thoughts and memories, the well-adjusted survivors had developed massive dream suppression which lead to almost complete amnesia regarding dreaming in general.

C.J. Fox
3/29/89

ONREUR REPORTS AND MAS BULLETINS

Reports

To request reports, indicate the report number (in parentheses after the title and author's name) on the self-addressed mailer and return it to ONREUR.

Chemistry

Scales of Hydrogen Bonding Workshop, by M.H. Abraham. (9-8-C) About 25 chemists took part in the ONREUR-sponsored workshop, "Scales of Hydrogen-bonding," held in London from 1 through 3 July 1987. The purpose of the gathering was to discuss current activities in setting up scales of both solute and solvent hydrogen-bond strength. The importance of solute hydrogen-bond scales is the understanding and prediction of effects in such diverse areas as solubilities in water and in blood, water-solvent partition coefficients, toxicological studies, and the response of chemical microsensor coatings to vapors. Work on scales of solute hydrogen-bond acidity and basicity is well advanced. Most of these scales are based on log K values for hydrogen-bond complexation in dilute solution – that is, they are nearly always Gibbs energy related scales. Theoretical work by I.H. Hillier (University of Manchester, UK) has demonstrated that such scales are likely to be more easily handled than scales based on enthalpies of complexation. P.-C. Maria and J.-F. Gal (University of Nice, France) described their multivariate analysis that leads to an angle Θ, descriptive of the electrostatic: covalent ratio in the base: reference acid complex. M.H. Abraham (University of Surrey, UK) showed that it was possible to demonstrate the virtual equivalence of a solute scale and a solvent scale of hydrogen-bond basicity for nonassociated compounds, provided that the reference acids in each case led

to Θ values that were almost the same – around 65°.

Computer Science

The 2nd International Conference on Vector and Parallel Computing, by J.F. Blackburn. **(9-1-C)** Summaries of the presentations by invited speakers to this conference, held in Bergen, Norway, are given along with the author's abstracts of the contributed and student scholarship papers. In all, summaries of 16 papers and the abstracts of 91 papers are included.

Communications

Coherent Multichannel Techniques for Integrated Broadband Communications Subscriber Lines, by J.F. Blackburn. **(9-2-R)** The work of Project 1032 of the RACE program definition phase is summarized. The background and problems relating to coherent multichannel techniques for integrated communications subscriber lines, assumptions, and recent relevant state-of-the-art developments are discussed, including a commentary on Level II of the RACE definition phase scenario (ROPS-3).

The RACE Program in 1988, by J.F. Blackburn. **(9-7-R)** The program called Research and Development in Advanced Technologies for Europe (RACE) was first planned in 1985. This report details the projects approved for the 5-year period beginning in 1988. The goal of the RACE program is to contribute to Europe-wide Integrated Broadband Communication.

Multidiscipline

EUREKA's Sixth Ministerial Conference, by J.F. Blackburn. **(9-4-C)** The proceeding of this conference are summarized, and a list of the 54 projects announced at the conference is given. The list includes title and description, participating countries, cost and duration, and status.

Optoelectronics

Joint Optoelectronics Research Scheme (JOERS) Conference, by J.F. Blackburn. **(9-5-C)** Summaries of the information made on 33 JOERS programs available at the conference are given. Also given are summaries of nine of the ten papers presented. Since the objective of the conference itself was to summarize the scheme's progress, this report provides a reasonably comprehensive picture of the UK's status in optoelectronics technology.

Space Science

COSPAR Meets in Helsinki, by R.L. Carovillano. **(9-3-C)** Proceedings of the 27th Plenary Meeting of the Committee on Space Research, held in Helsinki, are discussed. The discussion includes Soviet cosmonaut J. Romanenko's account of his epic space flight, interagency coordination of missions, and summaries of many papers under the heading of auroral topics.

Ionospheric Modification by Powerful Radio Waves – the 2nd Suzdal Symposium, by George J. Morales. **(9-6-C)** Presentations given at this conference, held in September 1988 at Tromso, Norway, are discussed. Topics include: parametric decay and Langmuir turbulence, electromagnetic emissions, satellite/rocket studies, large-scale density cavities, artificial ionization, and oblique heating. The author also reports on associated visits to EISCAT and the Swedish Intitute in Uppsala.

MAS Bulletins

The following Military Applications Summary (MAS) Bulletins were published between 1 December 1988 and 31 March 1989. The MAS Bulletin is an account of accomplishments in European naval research, development, test, and evaluation. Request copies of the Bulletins, by number, from ONREUR.

76-88	Prototype Voice-Activated Control System
77-88	CADS-Controlled Aerial Delivery System
78-88	Long-Life Coolers for Infrared Detectors
79-88	"VESTA," A Seawater Battery
80-88	Active Towed Array Sonar
81-88	Dynamic Ship Positioning – The Dypos Systems
82-88	Telescopic Masts – Lightweight Composite Structures for Quick-Erect, Heavy Duty
83-88	Manpack Portable Solar Battery Charging System
84-88	MAS Bulletin 1988 Annual Index
1-89	European Fighter Aircraft (EFA) Update
2-89	Cold Cutting System From GBI
3-89	Fuel Gas Generator
4-89	SAAB IRS-700 Passive IR Surveillance and Acquisition System
5-89	RC-35 Low-Level Air Defense and Ground Role Sight for 20mm to 40mm Cannon
6-89	Mandarin Computer-Based Training System Update
7-89	STRIX – 120 mm Mortar-Launched Anti-Armor Projectile
8-89	HELIOS – Helicopter Observation System
9-89	Anti-Tank Weapon System Helitow
10-89	GIRAFFE AT Radar
11-89	Adaptive Noise Cancellation at Plessey
12-89	Night Observation Device
13-89	Remote Controller Minesweeper
14-89	14th International Pyrotechnics Seminar 18-22 September 1989
15-89	French SODAR's (Sound Detection and Ranging)
16-89	Microtherm Thermal Insulation
17-89	New Krupp Atlas Marine Simulators
18-89	Soundtrak ASW Target Simulator
19-89	A Portable Scientific High-Resolution Echo Sounder from SIMRAD
20-89	New Acoustic Tide Gauge Tested
21-89	Swimmer Detection Sonar
22-89	Data Bus Network Testing S2460
23-89	Foreign Weapons Evaluation (FWE) and NATO Comparative Test Programs (NATO CTP)
24-89	Lucas Turreted Tround Gun System

THE EMBASSIES: TECHNOLOGY ROUNDUP

France

For further information on France items, contact Dr. Allen Sessoms, Science Counselor, American Embassy, Paris, APO NY 09777-9200.

Increasing Median Age of French Researchers. According to Research Minister Crozier, French scientific research suffers from the increasing median age of its researchers. Figures are self-explanatory. While the percentage of researchers under the age of 40 was less than or equal to 60 percent from 1950's to 1970, it dwindled in the 1970's and went down to less than 40 percent in the 1980's. French researchers' average age now is 43.

If the percentage of new hires into research institutes or if the scientific employment policy does not change, the average researchers' age will be 45.5 in 10 years; 63 percent will be over 40 years of age (against 62 percent currently) and 37 percent (against 22 percent currently) will be over 50. Crozier notes that a human grouping principally consisting of old persons naturally tends to maintain its norms and structures and to resist innovation. Therefore, the situation is not very encouraging.

Crozier acknowledges that progress has been made with respect to hiring in the 1980's. After the slack period of the seventies, numerous positions were created in the 1989 budget. Crozier wonders whether this will be sufficient. The percentage of new hires currently is 3 percent (of which 1 percent are new positions). If instead of 3 percent, there were 5 percent of new hires (and three times as many new positions), it would take 8 years for the age trend to be substantially modified. In order to obtain a noticeable qualitative change, it would be necessary to have 8 percent of new hires (and multiply by 6 the number of new positions). This appears totally unrealistic in view of budgetary constraints.

This situation is aggravated by the fact that researchers tend not to change jobs. In view of this, Crozier notes that the increase in the number of new hires in research institutes without a change in the rules governing careers can only have limited effects. For this reason, Crozier invites Research Minister Curien to consider the following points:

- The infusion of young blood into the staff must not only apply to statutory researchers. Non-statutory researchers will also have to play an important role. (In France, researchers employed by research institutions (which are public organizations in their great majority) hold the status of civil servant. They are called statutory researchers. This status is protective in that it affords security of employment, prevents dismissals, etc. All other researchers – such as those preparing theses, for example – are non-statutory.
- Researchers' careers become less and less attractive not only because of the relatively low level of remuneration within the public sector but also because of an environment that is seen as old.
- Movement between public and private research, between universities and research institutes, and between French and foreign laboratories must increase.
- The role of laboratories and research teams must be reviewed. Units must be of a human size to ensure training, orientation, and movement.
- Finally, the development of a human resource policy can only succeed if structures are renewed and new units created which are capable of adjusting to the profusion of rapidly evolving techniques and sciences.

Crozier recommends that a restricted commission of 3 to 6 internationally recognized scientists be constituted to review the problems and propose innovative solutions.

Research Minister Curien agrees with Crozier's analysis of the situation but has reservations concerning the solutions proposed. Curien first emphasizes that there must be no hasty decision. Errors done in the past must not be repeated. The current situation is due to decisions made in the 1960's. The numerous recruiting efforts made at the time contributed to the development of quality research in France but, in return, froze hiring in laboratories for 20 years. Curien doubts whether he should again resort to massive recruitment in order to reverse the age trend. According to him, France would have to pay for the consequences of such a policy in 25 years. The fact that France has 20 percent less researchers than its direct competitors does not, in his eyes, justify recruitments in bulk. Curien rather believes in regular recruitments which permit exchange between experienced and younger researchers. This is why nearly 3 percent of new positions (i.e., 600 positions) were created in the 1989 budget. The objective for the years to come is to replace 4 percent of the staff per year with young researchers. Curien emphasizes, however, that he does not wish to go any further for the time being.

Curien also indicates that he disagrees with Crozier's recommendation to include non-statutory researchers in the new policy. Curien is of the opinion that a researcher does not work efficiently in a nonpermanent position and is always in search for new contracts, when others in his laboratory are covered by the protective civil service status. Furthermore, Curien believes that such non-statutory researchers will, after a few years, ask to be tenured. This is what happened in the past in similar circumstances.

Curien is, however, in favor of training through research. He recently proposed that the number of theses be doubled in the next 5 years. He also agrees with Crozier when he states that there are not enough bridges between public and private research and between universities and research institutes. According to Curien, the mobility rate is too low. Several measures have already been taken to increase movement. Temporary assignments have been made easier. Also, in the promotion process, evaluation boards will have to take into account careers pursued outside of the researchers' initial employing establishment. Other measures will soon be taken to encourage researchers to interact more with industry.

Crozier's analysis is not in itself new. French officials and experts have for a long time emphasized that the increasing median age of French researchers is becoming a very serious problem, jeopardizing in the long run the competitiveness of French research. The reasons are well known: stop-go recruitment policies and lack of movement (due itself to sociology, tradition, a protective civil service status, promotion policy with too much emphasis on seniority, etc.). What is, however, new in Crozier's approach is that it is the first time, to the best of our knowledge, that this specific issue is singled out (and not cited as one of the problems confronting French research), reviewed at length, and brought to the Research Minister's direct attention. Such an action, in itself, shows that this will become a critical question as Europe approaches the single market and opportunities for young researchers become even more accessible in West Germany, the UK, and Italy. Contrary to his predecessors, Curien does not seem to want to define a policy under any kind of pressure. He really seems to be intent on putting an end to haphazard and short-

term policies which have been plaguing French research for so long. Researchers have indeed been complaining that they could not work efficiently because political rather than scientific considerations were a determining factor in establishing policies. They stated loudly before and after the 1988 presidential and legislative elections that scientific research needed long-term planning in terms of resources and policy decisions; and that scientific programing cannot change with each new administration. Whether Curien will have enough leeway or the ability to overcome sociological inertia, remains to be seen.

Four-Year Plan for the French Research Institute for Sea Exploitation (IFREMER) and Appointment of the New Director General. IFREMER serves simultaneously as a basic research center, as a technical support center for numerous economic activities in the maritime sector, and as an expert in case of conflicts. It was created 4 years ago as a result of the merger of the National Center for Ocean Exploitation and of the Scientific Institute for Maritime Fishing. Because the objectives of these two institutes were quite different, it took some time for IFREMER to become an organization in its own right. It seems that this has now been done since a 4-year plan (1989-1993) has officially been announced by Pierre Papon, the new Director General.

The 4-year plan for IFREMER that Papon recently presented defines a few objectives:

- To put sufficient emphasis on management of resources and of environment
- To exploit research and transfer technology to industry
- To promote cooperation between IFREMER and its partners
- To take into account regional and European realities without waiting for 1993 (the "blue" Europe already exists).

Concrete steps in this direction have already been taken. IFREMER participates in certain EUREKA programs such as HALIOS (Spain-France-Iceland) which proposes to build three ocean ship prototypes integrating leading-edge equipment for industrial fishing.

Another important project is the study of the quality of littoral water. The lack of both scientific and regional knowledge makes it indeed difficult to foresee the consequences of changes in the sea environment. Another priority program is the study of seaweed. These plants constitute the raw material for a rapidly developing industry (manufacturing of gelatin in the food, textile, or pharmaceutical industries).

Such programs make it necessary for IFREMER to be present in the South Pacific. This region is a natural laboratory of 30 Mkm^2, of which one-fifth is under French government control. This region is rich in deeps, in seismic zones, in mineral deposits, etc. Further, it lends itself well to satellite observation, such as that already in place with SPOT. Earth observation will be reinforced in 2 years when the European satellite ERS-1 and the French-American satellite Topex-Poseidon are put into orbit. The measurements made in space will have to be confirmed by analyses done on the spot. IFREMER will have experiments conducted by surface ships and deep-diving vehicles.

IFREMER's budget stagnated, and its personnel decreased, in 1987 and 1988. The additional funding granted last summer by the new socialist government enabled IFREMER to create 28 positions. F60 million ($10 million) were allocated to start building a new oceanographic ship. As of 1989, IFREMER employs 1200 persons and has a budget of F826.7 million ($138 million), of which F113.9 million ($19 million) are IFREMER's own resources. The 4-year plan anticipates a regular progression which, in constant francs, would bring the budget to F906 million ($151 million) in 1993.

Spain

For further information on Spanish items, contact Mr. Ishmael Lara, Science Counselor, American Embassy, Madrid, APO NY 09285-8500

Spanish Participation in EUREKA. EUREKA is a decentralized European R&D initiative which relies on private financing by corporations and research institutes as well as on government funding. The EUREKA Secretariat, which is based in Brussels, has branches in each member nation and serves as a clearinghouse and coordinating force for the initiative.

As of 1 July 1988 Spain has participated in 55 EUREKA projects and is involved in 12 more that are pending. France leads with 106 projects; followed by the UK, 73; West Germany, 64; and Italy, 59. The EC and 14 other European countries are also participating: (Austria, 20; Belgium, 27; Denmark, 27; Finland, 20; Greece, 8; The Netherlands, 52; Ireland, 6; Iceland, 2; Luxembourg, 3; Portugal, 13; Sweden, 33; Switzerland, 25; Turkey, 1; and the EC with 2 projects).

FAMOS (Flexible Automatisierte Montage Systeme) is a pilot program within EUREKA, with the objective of developing and promoting flexible, automatic assembly techniques. Several projects in the FAMOS series seek to apply these techniques to various industries. West Germany, the UK, France, Spain, Italy, Austria and Switzerland are the participating countries in FAMOS. Ireland, Denmark, the Netherlands, Finland, Norway, Greece, and Luxembourg have also petitioned to participate.

Following is a summary of EUREKA projects in which Spain participates.

1. Photronics Proposal. Industrial development of amorphous-silicon-based components for photoelectronic applications.
2. UPAC—Adaptive Garment Manufacturing Unit. Development for a garment factory incorporating the latest concepts in production and organization.
3. EUROLASER. Evaluation and development of industrial lasers for material processing.
4. COSINE. Cooperation for open systems interconnection networking in Europe.
5. Clinical Diagnosis of Gonorrhea. Development of a new range of immunodiagnostic kits for the rapid diagnosis of gonorrhea.
6. CARMAT 2000. Car structure using new materials. Investigation and definition of process and design of new fabrication techniques regarding car body production.
7. EUROCIM. Design and development of a group of flexible automated factories for the production of electronic equipment.
8. Advanced Mobile Robots for Public Safety. Involves third-generation fast-moving robots for public safety applications such as national disasters and antiterrorism (definition phase).
9. PARADI. Definition of a system of function management, design, production, and logistics adapted to different types of manufacturing operations involving a high level of technology.
10. DIANE. Automated integrated system for neutrography. Mobile neutron radioscopy equipment adapted to nondestructive testing of components and the study of new materials.
11. Chrome Tanning Salts Substitutes. Development of a method of obtaining quality leather for various uses which eliminates or reduces to a minimum the quantity of chrome required.
12. GALENO 2000. Development of new, noninvasive medical measuring methods and combining these with computer-aided diagnostics.
13. APEX—Advanced Project for European Information Exchange. Devel-

opment, evaluation, then marketing of a methodology for associated products and services for the computerization of exchanges of information in the context of large industrial cooperation programs.

14. EUROMAR. Development and application of modern technologies for the exploration of ecological relations and cause-and-effect chains in the seas of Europe.

15. Prospects for Construction Techniques. Creation of an industrialized urban infrastructure applicable on an identified site, using building techniques for the years 2000 to 2020.

16. EUREKA Software Factory. Development of a computer-aided system for the production of software (software production environment).

17. Ceramics for Diesel Engines. Development of new, efficient fiber-reinforced ceramics for diesel engines for commercial vehicles.

18. Sunflower Seeds. Production of new commercial varieties of sunflower seeds with high oil content, suitable for Mediterranean arid zone conditions.

19. EUROPOLIS. New, intelligent control system to aid urban and interurban traffic and advanced metropolitan information control and monitoring.

20. Oxodipine. Development of Oxodipine. Pharmacological and clinical development of oxodipine, a calcium antagonist, and studies of related structures.

21. Computerized Engineering Unit. New engineering working methods by the use of databases and appropriate applications, where users will be genuinely assisted by computerized systems.

22. FAMOS. European collaboration in the field of flexible automated assembly systems.

23. Water Trimming of Aluminum Machine Parts. Development of a system for machining aluminum parts using high-pressure water technology.

24. New Process for Obtaining Polymers. Development of acrylic monomers from lactic acid derivatives by fermentation, with the aim of obtaining polymers.

25. Development of Rhizobacteria Products. Develop microbial products for seedcoating to increase growth and crop yield. A strain selection program for corn, sunflower, sugarbeet, and soybeans.

26. BD 11. Development of a database for distributed expert systems on low-level computers, using the "pick" operating system and "C" language.

27. EUROLASER. EUREKA 25-kilowatt CO_2 laser cell project. Design and construction of an efficient 25-kw CO_2 laser module of good beam quality, capable in combination with similar modules of up to 100 Mw; beam manipulator and a suitable seam tracking system; validation of the laser cell.

28. FIABEX. Development of an expert system for safety and reliability analysis of industrial systems. Expert system for automatic calculation and representation of FMEA and fault-tree analysis, status graphs, and Petri nets for safety and reliability analysis for industrial subassemblies, operating systems, and complex industrial processes.

29. Electron Beam Welding. Second generation of high-power electron beam equipment for out-of-vacuum metal processing. Design and develop for industrial use a new and cost-effective method of welding steel of up to 100 mm thickness at atmospheric pressure.

30. HDTV. Compatible high-definition television system. Development of a 50-Hz-based HDTV system along an evolutionary development from the MAC-packet concept; AMD compatibility with MAC transmitters and receivers.

31. Fishing Vessels for the 1990's. Development of sophisticated technologies necessary for the design, construction, and operation of industrial fishing vessels, including prototypes.

32. Aerospace Intelligent Management and Development Tool for Embedded Systems. Supply European manufacturers in the aerospace field with distributed knowledge-based management system for the development and maintenance of embedded software.

33. Media for Large-Scale Mammalian Cell Growth and Maintenance. The technological developments resulting from the collaboration will result in improved products from which mammalian cells may be cultivated and will also enable production costs of such products as vaccines and monoclonal antibodies.

34. EUROFAR. European Future Advanced Rotorcraft. Aircraft combining helicopter-type vertical takeoff and landing with airplane-type high cruising speed, by tilting of two rotors mounted at the outer end of the wings.

35. EUROCARE. European Project of Conservation and Restoration. Development of presently not-available industrial products and technologies as well as craft skills for conservation and restoration work. Establishment of technical standards and guidelines for examination and treatment of objects and monuments.

36. Automatic Cutting Tool for Leather Industries. Automate the handling of material and cutting parts to eliminate use of dies, and to save on materials by using computer-assisted design and maximizing cutting efficiency for leather and furniture industry.

37. ESCAPE. European Strategic Cigar Automation. Product innovation which allows for preservation of European production, based on modern fundamentals and standards.

38. Advanced Finite Element Software for Analysis, Reliability Assessment, and Optimal Design of Large Engineering Structures. Exploitation and development of existing research, which over the last 5 years has made major advances in the solution of engineering problems in a number of different civil, structural, and geotechnical areas.

39. EUROPARI/Spider. Development of integrated flexible automated paperless design and production units for these type of parts, integrating all operations from design to control.

40. Diagnostic Procedure through Selective and Specific Filtration of Antigens or Labelled Antibodies. This project attempts to develop a diagnostic system or procedure of universal application, where the necessary and suitable reagents may be incorporated in order to achieve a concrete diagnosis of various pathological entities.

41. Low-Cost Medium-High-Feature Telephone Subsets Using BIMOS Technology. Development and use of BIMOS technology to integrate medium-feature telephone subset functions in one single chip.

42. Development of New Technologies in Nutrition and Genetics Improvement for the Industrial Culture of Bivalve Molluscs. Develop new techniques in order to optimize the industrial culture of flat oysters and Japanese clams.

43. SMART Motors for Domestic Appliances. Use of advanced power and high-voltage semiconductor devices in thermally efficient power modules for cost-efficient implementation of SMART electronic motor control for low- and medium-cost white line appliances.

44. Robot for Citrus Harvesting and Handling. Development of a robot prototype for detection, collection, and manipulation of citrus fruit.

45. Rapid Diagnosis of, and Vaccination against Canine Leishmaniosis. Provide veterinarians and health-care workers with new means of combatting this illness.

46. EUROLASER. 10-kw CO_2 Laser Modules and Related Systems. Lift the actual limitations of the diffusion of high-power laser manufacturing systems in industry by gas excitation and techniques, optical power extraction, and innovative welding and heat treatment procedures.

47. PHOEBUS – 30-mw Solar Demonstration Plant. Design, construct and operate a 30-mw solar power plant. Includes optimization and integration of components; cost reduction; and reliable, complete systems.

48. Allergy Innovations. Development of technology and kits for laboratory diagnosis of allergic and occupational diseases: kits for *in vitro* diagnosis of IGE- and IGG-mediated allergies and their application.

49. FAMOS - Flexible Manufacturing Cell for Telephone Assembly. The design, development, and installation of flexible assembly system (FAS) including the following subsystems: transport system/manufacturing equipment such as robot cells, test system, and control system.

50. *In Vitro* Immunization for Production of Monoclonal Antibodies to Gangliosides. Aim is to obtain monoclonal antibodies of human origin for treatment of certain neoplasic processes.

51. FAMOS – ARIA. The development of new automated assembly lines for large series of small and medium-sized products. The first application will be in the area of low-voltage mini-switches.

52. Transputer-Based APD/INMOS Language and Operating System Research. Formalization of technical requirements and specifications for the construction of parallel processing systems, develop a UNIX-compatible operating system for a class of multiple transputer systems, a C compiler, and an OCCAM compiler.

53. P-Phone. Development of a personal security system based on telephone sets for domestic and possibly mobile use, involving foolproof installation, low current consumption, and static intrusion sensing.

54. Space Bio Separation. A new separation process to isolate and purify high specific value biological products. The aim is to design a whole purification chain with optimal coupling, functioning under microgravity and sterile conditions.

55. Blood Donor Screening. Develop diagnostic assay panels for hepatitis infections/lymphotropic retrovirus, particularly HIV and HTLV I; increase diagnostic kit sensitivity/specificity; develop antigen diagnostic methods/*in vitro* antivirus human immunoglobulins.

56. Serological Determination of Syphilis. Planning, development, and industrialization of a comp'ete system made up of reagents and an automatic instrument for serological determination of syphilis.

57. Bit-Rate Reduction System for HDTV Digital Transmission. The definition of an algorithm and a CODEC structure for bit-rate reduction for HDTV transmission in contribution links, and the implementation of CODEC prototypes.

58. Development of Advanced Manufacturing/Computer-Integrated Manufacturing Technologies (Definition Phase). EUROPARI is a 1-year definition activity to define projects for the development of advanced manufacturing/computer-integrated manufacturing technologies which could benefit both the aerospace and nonaerospace industries.

59. FAMOS – Planet (Definition Phase). Feasibility study for electronic control units for automotive use.

60. Auto Farming Systems. Development of farming systems incorporating an autonomous navigator and adaptation to environment regulations by improving mechanical/chemical soil/crop precision treatment and use of driverless vehicles.

61. MEDIM - Medical Digital Information System. The project will contribute to containing health care expenses by improving organizational efficiency of the diagnostic imaging department using digital media. Establishment of a digital medical management system for hospitals.

62. Linear Train Motor. Development of high-power linear motors and experimentation for traction and other industrial applications.

63. Multilingual Product Description. Multilingual product description standardization for identification of supply/demand, customs tariff classification in world trade, combining terminology with harmonized commodity classification, and coding system of customs coop.

64. Synthetic TV. The design and production of a system by which realistic, synthetic TV scenery could be created and operated combining real-time computer-image-generation techniques with computer-assisted live shooting techniques.

65. FAMOS – Flexible Refrigerator Manufacturing Plant. The project aims at decreasing the cost of manpower in fabrication of refrigerators through desigr. of automizable products and making technology and organization more reliable and efficient.

66. FAMOS – Flexible Shoe Factory. Development of a flexible automated shoe factory, including two pilot plants (France and Spain). The second phase will include controlling production on one site.

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